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THOUSANDS OF RARE, BEAUTIFUL AND INTERESTING SPECIMENS

are also mentioned in the September *Leisure Hour* that would delight any collector. What is more beautiful than perfect *Sulphurs* from Sicily, *Pyrites* or *Hematite* from Elba, *Selenite*, some showing beautiful inclusions of crystallized *Sulphur* or moving bubble or *Aragonite*, from Sicily, or transparent cleavages of great size showing moving bubble, from Utah, *Smithsonite* of various colors from Laurium, Greece, *Paisbergite* of remarkable color from Sweden, *Calcites*, *Fluorites* and *Barites* in great variety from England; *Quartz* in wonderfully beautiful crystals and groups from Dauphiny, France; Herkimer Co. N. Y.; Hot Springs, Ark.; Switzerland, and Pike's Peak, Col.; the two last of beautiful smoky color; *Malachite* and *Azurite* crystallized and polished; *Wulfenite* and *Vanadinite* of various colors from Arizona and New Mexico; *Rubellite*, *Colemanite*, etc., from California; *Calcite*, *Zinc blende*, *Galena*, etc., from Missouri; *Apatite*, *Perthite* and others from Canada; *Amazon Stone*, *Pyrites*, *Smoky Quartz*, *blue Barite*, etc., from Colorado; *Amethyst*, *Native Copper*, *Chlorastrolites*, *Native Silver*, etc., Lake Superior region; *Wavellite*, *Variscite*, *Vesuvianite*, etc., Arkansas; *Pyrites*, *Chalcopyrite*, *Rutile*, *Byssolite in Calcite*, etc, Pennsylvania; *Brown Tourmaline*, *Prehnite*, *Rhodonite* var. *Fowlerite*, *Calamine*, *Willemite* yellow *Axinite*, etc., New Jersey; *Chondrodite*, *Clinochlore*, *Tourmalines*, etc., New York.

The above are only a few of the many beautiful species mentioned in our September, 1894, *Leisure Hour*, and in the Catalogue.

Of the vast number of rare and interesting species mentioned, space will only permit mention of *Boléite*, *Cumengéite*, *Sphaerocobaltite*, *Remingtonite*, etc., from Boleo, Mexico; Finely crystallized *Molybdenite* in the gangue, *Twin Zircons*, etc., from Canada; *Hauerite*, *Native Lead*, *Kentrolite*, *Matlockite*, *Phosgenite*, etc., etc.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. LXI.—*Inversion of Temperatures in the 26·68 day Solar Magnetic Period;** by FRANK H. BIGELOW.

The Epoch and use of the Ephemeris.—In previous abstracts, containing some of the results of my research into the relations between solar magnetism and meteorological phenomena, no complete account has been given of the formation of the Epoch and general use of the Ephemeris. A brief statement, however, interposed at this place, may be of service to some who are interested in this subject. The Ephemeris depends chiefly on the European Stations, Greenwich, Paris, Pola, Prague, Vienna, Pawlowsk, and Tiflis, the mean geographical position of the group being, longitude 17° 7′ east, and latitude 48° 37′ north. Each of these stations reports 24 observations of the three components of magnetic force every day, and the mean of these values, therefore, is equivalent to an ordinate on the scale of abscissas at noon of the station. Certain periodic changes were found in the system of deflecting forces that emerged from the daily residuals, of which one type was peculiarly conspicuous. The first day following this principal change was called number one of the new period, and from such dates the mean epoch for the year 1887 was computed, namely June 12·22, being very near the middle of the last quarter of the century. Strictly this applies to the position at longitude $1^h\ 8^m\ 28^s$ east, but not thinking the data of astronomical accuracy, I have in my work taken the epoch as practically Greenwich mean time, the correction being −0·05 day, if applied.

* Communicated by permission of the Chief of the Weather Bureau.

The meteorological observations of the U. S. Weather Bureau are now made at 8 A. M. and 8 P. M. 75th meridian mean time, and as it is generally agreed that the arithmetical mean of these values is nearly equal to that derived from hourly observations, this has been used in reducing the variations from day to day. In some of the years, if necessary, the mean of the maximum and minimum readings is taken as the mean for the day. In every case this mean corresponds to a noon observation at the station, as with European stations, and therefore a correction for longitude is required for the epoch of the ephemeris. I have preferred to retain the Greenwich epoch throughout the computations, and then move the comparison magnetic curve to the right by the amount of such correction. It has been found that the variations of the meteorological elements synchronize closely with the fluctuations of the magnetic curve in the extreme northwestern states, Manitoba, North and South Dakota, and Montana. If the temperature changes are transferred to millimeter paper, so that one centimeter is equivalent to a day, then for this region there is only a small correction to the epoch of the corresponding magnetic curve. If we could have our observations at a proper origin in British Columbia, no correction would be needed, and such an origin is 115° W. longitude, 55° N. latitude. This seems to be physically determined by the peculiar meteorological conditions of North America, namely, the latitude of the high pressure belt, and the winter accession to the same from the Arctic regions, which passes near this origin; the neighborhood of the pole of maximum cold and maximum magnetic intensity; the nearness to the magnetic pole in Boothea Island; all of which in combination cause this region to be a special theatre of formation of the high and low areas that are the agencies causing many of the weather variations of the United States. Passing to the south and east of this origin one can follow the changes produced by the temperature waves, by simply moving the magnetic curve to the right a number of days equal to the time of progress from the origin eastward. In practice, the calendar dates have been written along the top of the sheet and underneath them the dates of the magnetic ephemeris. Beginning at the day with its fraction which starts a new period, a line is drawn down the sheet so that it passes through the same phase for each district of the country. This was always determined by matching the magnetic curve to the temperature curve. Hence the same phases may be collected together by counting this line as the beginning of a period in every case. The difference between this line and the straight lines drawn from the ephemeris date gives the time consumed in the eastward drift. Since in this way the longitude from Greenwich

has not entered, the final result as plotted on a curve will match the mean magnetic curve by moving the latter about eight hours to the right.

Since the epoch is that of the mean ordinate corresponding with noon, the real beginning of the magnetic curve is twelve hours earlier. There is this practical advantage in retaining the ephemeris on the noon ordinate, namely, that in following the fractional part of the dates, this ordinate may oscillate between the one and the ninety-nine hundredths of a day, and yet without changing the name of the day when it exceeds fifty hundredths. Therefore in tabulating data through many periods the integer date of the day can be always taken and the fraction neglected, since it is clear that the oscillation due to fractions of a day will soon balance themselves. The convenience of this device in practical work is very evident.

There are some plausible reasons for adopting the *115° meridian west longitude as the prime meteorological meridian for the United States.* Near it is the junction of the high polar circuit with the midlatitude circuit; the low pressure belt is thus chiefly interrupted by temperature waves at this point; near it is the greatest range in the temperature intensities; from it most conveniently can be computed the rate of the eastward march; the weather conditions originating on this stage of the meteorological field are propagated with such other variations as are due to the relaxation and disintegration of the same across the United States; the convenience of a meridian for meteorological reductions and the use of the ephemeris; the simple practical correction, half a day, from European to American phenomena. One point should be carefully remembered by meteorologists. It is necessary to distinguish between the phenomena of the pure ether and of ponderable matter. Magnetic forces are due to ether stresses alone, and hence those produced by the solar field are cosmical, and act instantaneously as well as simultaneously over the whole earth; when this ether energy is absorbed by the gases of the atmosphere, the forces are converted into those having their seat in ponderable matter, and hence the time factor due to convection or conduction must not be disregarded. Now the polar magnetic field chiefly concentrates in British America, and this combined with the general movements of the air causes the resulting temperature effects to be felt in other places only as the motion of the air allows them to spread. Hence at other stations, as in the east of the United States, the time discrepancy between the variations of the magnetic field and the temperature changes differ by three or four days. It is necessary to add to the epoch of the ephemeris this number to bring the synchronism approximately to view.

The temperatures of the United States have been plotted on long rolls, as described in my paper of January (Astron. and Astro-Physics), 1894, for more than 30 periods beginning 1892, Jan. 18·06, and continuing to date, and including the sixteen districts into which the synopsis of temperatures was subdivided, the Yuma district not participating in these changes. The time of the eastward movement from the origin, to the mean geographical position of the district to which the last station included in the group gives the name, is as follows in days and tenths of a day, for three different series of months, in each of which the rate is approximately the same. It will be necessary to say something more regarding the winter and the summer circuits of the movement, in a later section of this paper.

Eastward movement of the Temperature Waves of the United States from the position, Long. 115° W. Lat. 55° N.

Name of District.	Mean Longitude.	Mean Latitude.	December, January, February, March.	April, May, June, July, August.	September, October, November.
1. Roseburg	122° 33′	46° 42′	0·1	0·1	0·1
2. Calgary	107 43	50 46	0·3	0·3	0·2
3. Salt Lake City,	109 7	44 59	0·8	0·7	0·5
4. Fort Buford ..	99 42	45 8	1·1	1·1	0·7
5. Sioux City	96 20	39 43	1·4	1·6	1·0
6. Tucson	103 29	37 24	1·7	2·0	1·2
7. Corpus Christi,	95 13	31 34	1·8	2·3	1·5
8. Saint Louis...	91 40	41 42	2·1	2·6	1·9
9. Duluth	87 8	44 41	2·2	2·9	2·0
10. Saugeen	81 51	46 37	2·4	3·2	2·7
11. Port Huron ..	80 44	42 24	2·6	3·5	2·9
12. Pittsburg	84 43	37 55	2·7	3·6	3·1
13. New Orleans .	87 15	31 14	2·7	3·7	3·3
14. Key West ...	79 41	32 32	2·8	3·8	3·4
15. Washington ..	73 43	40 58	2·9	3·9	3·5
16. Northfield	67 51	45 58	2·9	3·9	3·5

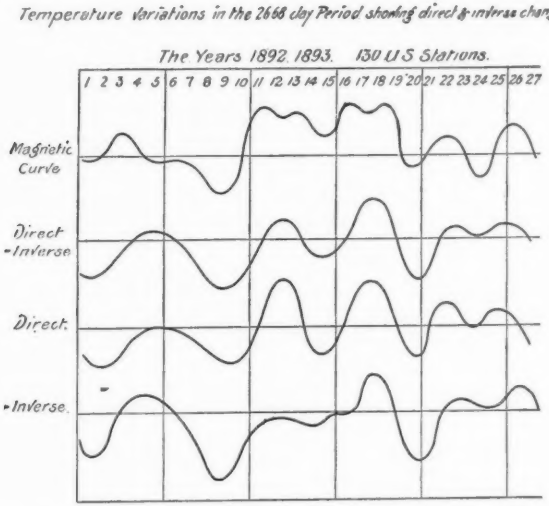
Inversion of Temperatures.—In accordance with the method established for reducing all temperature variations to the origin, and using the rates of eastward movement as given in the preceding table, a series of periods, thirty in number, from Jan. 18·06, 1892, to Dec. 11·74, 1893, inclusive, have been thus treated. One hundred and thirty stations, arranged in sixteen groups, were taken and the mean of the 8 A. M. and 8 A. M. tabulated. These groups were arranged in four divisions:

I. Roseburg, Calgary, Salt Lake City, Fort Buford.
II. Sioux City, Tucson, Corpus Christi, Saint Louis.
III. Duluth, Saugeen, Port Huron, Pittsburg.
IV. New Orleans, Key West, Washington, Northfield.

The mean temperature of each division for each day was taken out; then the mean temperature for the period from these means, and also the mean temperature from the middle of one period to the middle of the next; from these last means were interpolated values for each day; finally the differences between these two sets of numbers gives the daily departure of temperature. In this way the annual changes of temperature, due to the motion of the sun in latitude were to a considerable extent eliminated. The final sum of these residuals for each day is entered in the accompanying table. It will be observed that they are divided into two nearly equal parts which was accomplished as follows: The residuals of each period were plotted on half centimeter paper, and the line of variation of temperature drawn through them. These curves were carefully compared with the mean magnetic curve, which represents the intensity of the solar field, by superposition, when it was easily seen that certain periods agreed with the magnetic curve in its direct position, and others with the same curve inverted on its long axis. The magnetic curve is transferred to transparent celluloid, so that such comparisons are very easily performed.

The consideration of these curves disclosed some conditions, which are inherent in this type of work. They are the final effect of a number of causes. (1) The temperature gradients produced by the equatorial field, together with the wind currents by which heat is transported from station to station; (2) The annual change of the sun in latitude; (3) The rotation of the sun on its axis carrying the polar magnetic field. The result of these variations is to cause the formations of the individual curves corresponding to the solar rotation to be quite loosely constructed. The phases may fall a little to one side of the mean date, the amplitude of the crests is not uniformly built up, the mean elevation of the curve changes in an irregular manner, and the inversion of the curve may fall somewhere within the period. The magnetic curve itself is one of rapid variation, and hence it is difficult for it to persist steadily under all these sources of disturbance, so that the tendency of the residuals to cut themselves down algebraically must be admitted. The mean curve can be found only by using an extensive series of data, and ascribing to the small surviving residuals a larger degree of importance than at first sight they might seem to justify. These have been regarded as true relative numbers, and the final residuals have been restored to their proper magnitude, which can easily be concluded from the tabulations, by use of an appropriate factor. The residuals are thus to be considered as relative numbers, rather than absolute values in themselves, the magnitude of the single curves,

without regard to the phase times, controlling the amplitude of the crests. It must be remarked that nothing less than a very accurate determination of the period of rotation of the sun, would permit the survival of any residuals in such an irregular curve. Hence by as much as there remain residuals, which being derived from very different sources yet produce the same curve, the argument in favor of the existence of the system of forces in nature corresponding to them is greatly strengthened.


Temperature Variations in the 26.68 day Period showing direct & inverse charges
The Years 1892. 1893. 130 U.S. Stations.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Magnetic Curve
Direct - Inverse
Direct
- Inverse

Since the labor of constructing such elaborate tabulations is very great, especially in extending the same over a series of years, resort was had to a shorter process for the years 1878–1891. It had been observed that the temperature variations of the Dakota Stations were the least distorted from the fundamental curve, doubtless due to the continental location, the amplitudes being large and the phases steady, and hence five stations, Fort Buford, Bismarck, St. Vincent, Moorhead and Huron, were employed for this purpose. By a similar method, allowing one day for the reduction to the origin, the following table and curves were constructed. In the case of each system of curves the plotting is moved 8 hours to the left to allow for the longitude on the Ephemeris not yet taken into the count, the rule covering all cases being, "For any station correct the epoch and succeeding dates of the Ephemeris by adding the longitude from Greenwich and the time of eastward movement from the American origin."

Residual Variations in the direct and inverse types.

Direct Temperatures.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1892	Jan.	18·06	− 3·9	+ 3·6	+ 1·8	+4·8	+7·2	+1·6	+ 0·3	+ 1·6	+ 4·3	+ 4·3	+ 4·8	+8·4	+ 6·5	+ 4·3
	Feb.	13·74	−11·3	− 3·8	− 2·4	−2·2	−0·5	+1·0	+ 2·4	+ 3·6	+ 3·1	+ 2·0	− 1·1	−0·5	+ 1·5	+ 0·8
	Apr.	7·10	− 6·7	− 4·4	− 1·5	−1·6	−4·3	−2·9	− 0·9	+ 2·8	+ 1·9	− 0·4	− 0·6	−0·1	− 0·8	− 1·3
	May	3·78	− 3·0	− 3·6	− 2·2	−2·5	−4·9	−2·3	− 1·0	+ 1·6	− 1·4	− 1·9	− 2·0	+2·1	+ 0·2	− 6·3
	Nov.	6·54	− 8·8	− 5·9	− 3·1	+2·5	+6·8	+3·9	+ 3·9	+ 5·6	+ 2·6	− 1·0	− 0·8	−1·6	− 2·7	− 8·3
1893	Jan.	25·58	+ 6·4	+ 3·8	− 0·5	+1·7	−1·1	−9·1	−10·7	−14·5	− 1·0	− 3·3	−13·4	−8·8	+ 4·4	+ 4·1
	Feb.	21·26	+ 2·9	+ 1·8	− 0·6	+2·1	+0·6	−1·2	+ 0·9	+ 1·1	− 9·4	−10·9	− 5·1	−1·0	+ 7·1	+ 9·5
	Apr.	15·62	− 0·4	− 2·4	− 6·0	−5·5	−5·3	−2·6	+ 0·1	− 0·5	− 1·5	− 0·8	− 0·1	−1·0	− 1·9	− 3·3
	July	4·66	+ 0·4	− 2·9	− 1·9	+0·2	+1·7	+2·4	+ 1·9	+ 2·8	− 0·2	− 0·3	− 1·7	−1·7	+ 0·7	+ 1·7
	Sept.	22·70	− 5·2	− 6·8	− 5·4	−3·7	−3·6	+2·1	+ 2·0	+ 1·1	− 1·0	− 0·6	− 0·4	+1·4	+ 1·3	+ 3·6
	Oct.	19·38	+ 2·0	+ 4·4	+ 5·6	+0·2	+0·2	0·0	− 0·8	− 4·2	− 7·3	− 6·9	0·0	+6·3	+ 3·0	− 4·2
	Nov.	15·06	+ 5·1	− 1·1	− 5·5	−2·1	+4·2	+4·8	− 4·1	−11·0	− 8·9	− 1·5	+ 5·1	+5·8	+ 6·7	+ 1·9
	Direct	...	−22·5	−17·3	−21·7	−6·1	−1·2	−2·3	− 6·0	−10·0	−18·3	−21·3	−14·6	+9·3	+26·2	+ 2·5

		15	16	17	18	19	20	21	22	23	24	25	26	27
1892	Jan.	18·06	+ 1·4	− 0·6	− 0·4	+ 3·5	+ 2·8	− 0·5	− 2·8	− 0·3	− 6·3	− 4·0	+ 3·3	− 1·1	− 10·5
	Feb.	13·74	− 3·8	− 0·6	+ 2·7	+ 5·5	+ 5·1	+ 5·9	−14·3	+ 7·6	+ 6·7	− 3·0	− 3·0	+ 4·9	− 0·8
	Apr.	7·10	− 3·4	− 1·3	+ 3·4	+ 5·1	+ 2·6	− 1·7	− 1·0	+ 4·4	+ 2·8	+ 1·9	+ 1·9	− 0·7	− 1·2
	May	3·78	− 8·2	− 8·4	− 6·3	− 1·8	+ 0·3	− 1·7	− 2·4	− 1·6	+ 0·5	+ 0·5	+ 2·8	+ 2·2	− 1·5
	Nov.	6·54	− 7·3	− 3·9	− 2·4	− 2·2	− 1·5	− 2·6	− 0·6	+ 2·6	+ 4·0	+ 5·5	+ 3·0	+ 1·5	+ 6·7
1893	Jan.	25·58	− 1·0	+ 2·1	+ 6·8	+ 9·8	+ 0·1	− 0·9	− 2·0	+ 2·4	+ 1·8	− 1·2	+ 2·1	+ 3·5	+ 4·8
	Feb.	21·26	+ 9·4	+ 9·8	+ 5·7	+ 4·9	+ 0·7	− 9·6	−11·6	− 9·4	−10·0	− 8·9	− 1·7	+ 0·4	+ 1·7
	Apr.	15·62	− 3·0	− 2·8	− 0·7	− 1·1	− 2·0	− 1·4	+ 1·7	+ 4·5	+ 6·6	+ 3·0	+ 2·1	+ 3·4	+ 1·7
	July	4·66	+ 1·7	+ 0·6	+ 1·4	+ 3·6	+ 1·3	− 0·2	+ 0·3	+ 0·4	+ 0·4	− 0·1	− 1·7	− 0·4	+ 1·6
	Sept.	22·70	+ 5·5	+ 4·8	+ 4·4	+ 3·6	− 0·5	− 3·4	− 5·4	− 4·4	− 1·1	− 0·1	+ 0·9	+ 1·1	+ 1·9
	Oct.	19·38	− 2·8	+ 0·2	+ 2·8	+ 5·6	+ 4·7	+ 4·2	+ 4·3	+ 4·4	+ 3·3	+ 1·2	− 1·4	− 5·8	− 1·3
	Nov.	15·06	− 5·8	− 9·8	− 6·3	− 9·8	− 1·1	+ 0·9	− 4·0	+ 1·0	+ 5·5	+ 1·5	− 1·7	− 2·7	− 12·2
	Direct	...	−17·3	− 9·9	+10·7	+26·9	+12·5	−11·0	−19·2	+11·6	+ 7·6	− 1·4	+ 6·5	+ 6·3	− 9·1

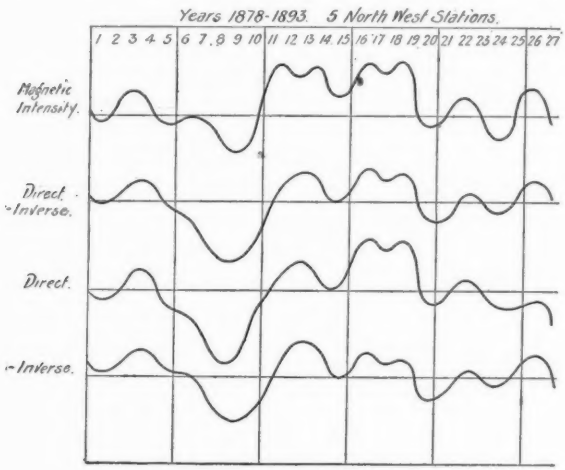
Inverse Temperatures.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1892	Mch.	11·42	− 4·3	− 6·6	− 9·2	−10·4	−11·5	−8·4	− 9·0	− 9·0	+ 3·6	− 2·0	− 0·6	+1·5	+ 3·4	− 0·8
	May	30·46	− 2·3	− 0·7	+ 0·2	+ 0·8	− 0·5	+1·1	+ 3·6	+ 3·4	+ 4·6	+ 7·5	+ 8·4	+5·8	+ 4·9	+ 5·3
	June	26·14	+ 0·4	− 0·7	− 0·9	− 0·8	− 3·0	−3·5	− 3·0	− 1·1	− 0·8	+ 0·3	− 1·9	0·0	+ 1·4	+ 2·5
	July	22·84	+ 4·2	+ 3·4	+ 3·2	+ 0·9	− 3·1	−2·6	− 1·6	− 1·4	− 0·1	+ 0·6	+ 0·7	+1·0	+ 2·3	+ 2·6
	Aug.	18·50	− 1·4	− 1·0	− 0·1	0·0	+ 0·2	+0·4	+ 0·8	+ 2·2	+ 2·0	− 0·8	− 3·2	−1·9	+ 1·3	+ 2·1
	Sept.	14·18	+ 1·4	+ 7·5	+ 6·9	+ 6·7	+ 7·1	+9·5	+10·6	+ 9·8	+ 8·3	+ 6·2	+ 2·8	+4·5	+ 2·5	+ 3·2
	Oct.	10·86	+ 3·0	+ 5·5	+ 2·5	+ 1·0	+ 4·5	+2·0	0·0	0·0	0·0	− 0·5	− 3·6	−5·5	− 6·0	− 4·7
	Dec.	3·22	+ 8·0	+ 6·1	+ 2·4	− 1·3	− 2·9	−3·6	− 0·6	+ 3·3	+ 5·9	+ 5·7	+ 4·6	+2·1	+ 3·1	+ 0·9
	Dec.	29·90	+ 7·9	+ 2·6	+ 1·0	+ 2·8	+ 1·9	+1·6	+ 1·5	+ 2·0	− 1·1	− 3·9	− 2·2	−5·5	− 6·7	− 7·1
1893	Mch.	19·94	+ 0·5	+ 4·4	− 0·6	− 5·2	− 5·7	−6·1	− 4·1	+ 1·3	+ 6·3	+ 7·0	+ 1·5	+3·9	+ 7·9	+ 5·7
	May	12·30	+ 0·5	− 1·1	+ 0·5	+ 3·1	+ 5·7	+4·4	+ 3·3	+ 0·2	− 4·1	− 2·9	− 3·8	−5·7	− 5·4	− 3·4
	June	7·98	− 0·4	+ 2·9	+ 3·3	+ 2·6	+ 0·3	−1·5	+ 0·5	− 2·7	+ 4·2	+ 3·5	− 0·4	−2·1	− 1·8	+ 0·4
	July	31·34	+ 1·8	+ 2·6	+ 0·6	+ 0·2	+ 1·4	+2·2	+ 1·7	+ 2·5	+ 0·6	− 3·4	− 3·3	−0·5	− 0·5	− 0·8
	Aug.	27·02	− 3·5	− 3·1	− 1·9	− 3·7	− 1·7	−0·2	+ 1·3	+ 1·2	+ 0·9	+ 0·6	+ 1·9	+2·2	+ 1·6	+ 3·3
	Dec.	11·74	− 6·5	+ 3·8	− 0·5	− 4·7	− 0·7	+0·8	− 3·1	+ 0·6	+ 8·6	+13·1	+12·6	+6·9	− 2·6	+ 0·9
	Inverse	...	+ 9·3	+25·6	+ 7·4	− 8·0	− 7·5	−3·9	+ 1·9	+17·7	+38·9	+31·0	+13·5	+6·7	+ 5·4	+ 9·1
	D−I	.....	−31·8	−42·9	−29·1	+ 1·9	+ 6·3	+1·6	− 7·9	−27·7	−57·2	−52·3	−28·1	+2·6	+20·8	− 6·6

		15	16	17	18	19	20	21	22	23	24	25	26	27
1892	Mch.	11·42	− 0·9	− 0·4	+ 2·4	+ 1·4	+ 7·1	+ 7·9	+ 7·1	+ 8·6	+ 7·1	+ 4·6	+ 6·7	+ 1·2	− 4·4
	May	30·46	+ 4·7	+ 3·5	+ 2·9	+ 3·7	+ 5·1	+ 4·9	+ 4·5	+ 1·6	− 0·1	− 1·9	− 1·5	− 0·4	+ 0·6
	June	26·14	+ 1·6	+ 1·5	+ 0·2	− 2·9	− 1·8	− 1·3	+ 0·6	+ 0·5	+ 1·1	+ 1·5	− 7·1	+ 3·3	+ 3·8
	July	22·84	+ 3·5	+ 2·0	+ 1·1	− 2·0	+ 0·2	− 0·8	− 1·7	− 1·7	− 3·0	− 3·2	− 1·8	− 1·3	− 1·6
	Aug.	18·50	− 0·1	− 3·2	− 3·1	− 3·5	− 0·6	+ 1·1	+ 1·2	+ 0·8	− 3·1	− 1·7	− 2·2	− 3·4	− 3·0
	Sept.	14·18	− 0·6	+ 1·2	+ 2·2	− 0·2	− 2·5	− 1·4	+ 0·3	− 1·1	− 4·6	− 3·3	− 2·2	+ 0·2	+ 2·4
	Oct.	10·86	− 1·8	− 2·3	− 0·9	+ 0·6	+ 1·0	+ 2·7	+ 1·6	− 2·6	− 2·7	+ 2·4	+ 3·3	− 0·3	− 5·5
	Dec.	3·22	− 4·1	− 6·5	− 7·2	−10·4	− 8·6	− 7·3	− 5·8	− 9·2	− 7·4	− 1·1	+ 4·9	+ 8·8	+ 10·5
	Dec.	29·90	− 8·8	− 6·8	− 2·7	− 2·8	− 2·7	+ 2·2	+ 4·4	+ 8·5	+10·2	+10·8	+ 8·0	− 0·4	+ 3·2
1893	Mch.	19·94	+ 2·5	+ 4·6	+ 8·1	+ 2·2	− 0·3	+ 1·0	+ 4·3	+ 5·6	− 2·3	− 6·5	− 4·9	− 2·7	− 1·1
	May	12·30	− 2·2	− 0·2	− 0·3	− 0·2	+ 1·2	+ 1·9	+ 0·6	− 2·3	− 1·9	+ 0·4	+ 1·8	+ 1·3	− 0·6
	June	7·98	− 0·7	− 1·4	− 2·3	− 0·3	− 0·3	− 0·1	− 0·6	− 0·9	− 0·7	+ 1·3	+ 1·3	+ 2·4	+ 1·7
	July	31·34	− 0·9	− 0·7	− 0·7	− 0·3	+ 0·4	+ 1·6	+ 2·3	+ 2·5	+ 1·7	+ 1·9	+ 1·6	+ 0·1	− 3·5
	Aug.	27·02	+ 4·2	+ 6·7	+ 4·9	0·0	− 0·2	+ 2·0	+ 4·6	+ 0·9	+ 1·5	+ 1·3	− 0·7	− 1·9	− 5·6
	Dec.	11·74	+ 7·1	+ 3·0	− 4·3	− 5·8	− 1·3	+ 4·1	+ 6·3	+ 2·3	− 2·7	− 4·4	− 10·9	− 12·2	− 9·9
	Inverse	...	+ 4·7	+ 1·0	+ 0·2	−20·5	− 1·3	+18·5	+29·7	+13·5	− 6·9	− 1·4	− 3·7	− 5·3	− 13·0
	D−I	.....	−22·0	−10·9	+10·5	+47·4	+15·8	−29·5	−48·9	− 1·9	+14·5	0·0	+ 10·2	+ 11·6	+ 3·9

In each diagram the first curve is the solar magnetic intensity, the second the direct temperatures minus the inverse temperatures, the third the direct and the fourth minus the inverse temperatures by themselves. The inverse residuals have all the signs changed so as to bring out the conformity to the eye. The factors used for the successive curves to reduce to the magnetic amplitude is 1, 1, $\frac{1}{2}$, $\frac{1}{10}$, $\frac{1}{5}$, $\frac{1}{15}$ respectively.

Temperature variations in the 2668 day Period showing the Direct & Inverse Types.


Years 1878-1893. 5 North West Stations.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Magnetic Intensity.
Direct - Inverse.
Direct.
- Inverse.

A few words only, on these remarkable curves are needed. There can be no collusion between the magnetic and the temperature variations, because the magnetic curve depends exclusively upon European observations, there being none available in America; the magnetic curve was published before work on the temperatures was commenced; the argument is estopped that the change of temperature as a meteorological phenomenon is what affected and was observed in the magnetic field. On plotting all the curves from year to year it is easy to match the magnetic curve yearly and the result shows that the solar rotation period is very exact, since there is no tendency to sidle, in about 220 revolutions of the sun. This result carries with it the conclusions, that the sun has a nucleus in which the permanent magnetism resides; that the period of rotation corresponds to the solar equatorial belt and not to the sun spot belts in latitudes $\pm 12°$; that the corona is at least in part a magnetic phenomenon, since from it was first deduced the fact

Direct and Inverse Temperature Variations. 5 Northwestern Stations, 1878–1893.

Direct Temperatures.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Sum.	D.	D+I.
1878	− 9	− 7	− 3	− 3	− 4	−24	− 30	− 14	2	14	20	6	− 14	− 8	−20	−16	4	0	2	−14	− 3	9	− 5	− 23	−36	−10	11	311	−142	−332
1879	5	7	14	19	1	10	− 18	− 5	− 27	18	1	− 4	3	− 28	−20	16	7	26	51	14	− 19	−50	−36	− 18	1	11	− 16	444	− 9	− 34
1880	7	18	5	− 8	2	−13	− 26	− 31	− 12	− 9	− 15	12	18	29	10	9	47	19	−12	− 23	— 24	−22	2	− 31	−45	− 6	48	503	+ 50	− 48
1881	− 6	− 1	6	13	15	− 1	− 31	− 6	20	− 16	− 15	4	16	3	7	9	19	32	28	− 3	− 14	14	19	− 27	−39	21	37	402	− 51	− 84
1882	4	7	11	18	15	−20	− 65	− 60	− 79	− 29	− 14	−30	18	− 13	28	47	29	17	30	3	− 14	20	−16	− 30	−32	− 6	8	663	+ 210	+ 30
1883	−29	− 5	23	33	17	32	22	− 2	− 20	− 25	− 23	− 3	− 4	15	− 8	5	24	0	−11	− 7	24	21	− 7	− 15	20	24	− 4	423	− 30	−116
1884	9	−17	−30	16	28	− 5	− 12	− 24	− 63	− 36	− 8	37	15	5	5	24	36	11	28	27	12	11	13	10	19	2	22	525	+ 72	+ 82
1885	−18	− 3	0	8	−21	− 43	− 47	− 64	− 83	− 60	− 53	−36	− 30	− 21	−34	4	− 1	27	53	29	46	74	58	51	26	7	30	927	+474	+543
1886	14	13	20	39	13	9	23	− 2	− 30	− 9	12	18	16	27	24	14	23	9	10	−14	− 27	−19	− 2	6	−27	− 23	− 15	458	+ 5	+132
1887	−28	3	19	21	4	−15	− 32	− 15	− 17	− 32	− 11	1	14	31	−24	−13	− 2	29	50	14	− 2	5	25	19	14	19	− 16	505	+ 52	+187
1888	− 5	0	8	− 5	− 9	7	0	11	− 9	9	15	22	35	7	−16	−13	− 7	1	− 9	−11	− 17	−18	− 2	0	5	27	9	277	−176	+207
1889	22	15	7	8	−28	− 9	10	− 22	− 54	− 22	− 4	20	12	21	8	13	12	17	22	−17	19	−19	−15	− 2	−16	− 5	− 24	439	− 14	+ 24
1890	6	− 5	−20	− 4	0	− 2	− 1	− 11	− 21	− 20	8	11	17	3	2	− 6	−10	−16	−17	−23	− 19	−13	−14	5	14	17	21	206	−247	−111
1891	−16	−22	−56	− 17	− 1	− 3	− 24	− 1	7	− 11	− 20	−23	21	27	16	27	33	29	7	−14	− 16	−19	−18	− 6	−10	3	− 9	456	+ 3	− 10
1892	−39	− 5	−20	− 3	− 4	4	2	9	13	7	16	25	15	4	0	6	13	2	5	− 5	− 5	10	12	5	6	11	− 6	237	−216	−361
1893	6	− 5	−26	− 24	−28	−22	− 23	− 40	− 46	− 38	− 32	−19	− 5	− 17	10	− 8	18	12	8	12	− 7	4	17	9	15	11	12	474	+ 21	− 88
Sum	−77	− 7	−42	111	−56	−95	−272	−277	−459	−259	−125	41	147	85	− 7	118	245	215	245	−32	− 66	9	31	− 47	−85	103	108	453		

Inverse Temperatures.

1878	0	15	7	19	13	4	3	2	1	− 4	− 1	− 5	− 6	− 6	−11	−11	−14	− 8	1	8	17	14	9	15	20	− 2	− 11	227	−190	....
1879	−25	−51	−31	− 8	12	− 6	19	13	26	37	6	17	24	− 6	− 9	5	− 4	− 9	2	14	12	4	3	20	22	15	17	417	− 25	....
1880	4	31	36	22	19	19	25	25	8	− 2	− 3	− 5	− 8	8	− 2	−15	−15	−15	−18	− 6	2	3	15	3	− 6	− 9	− 20	344	− 98	....
1881	35	23	4	12	−10	12	8	10	3	23	8	−27	− 28	− 43	−27	− 7	16	0	−20	15	14	− 4	−17	− 1	−10	16	28	409	− 33	....
1882	− 2	10	16	− 6	−23	−23	− 6	3	9	5	12	− 9	− 12	2	18	13	9	− 5	− 5	−15	− 6	− 3	− 5	4	− 9	−11	− 11	262	−180	....
1883	− 1	− 8	− 9	− 7	− 1	−11	− 1	− 3	− 13	− 10	0	−17	− 25	− 36	−36	− 6	− 6	14	27	25	27	18	6	16	−15	−14	− 4	356	− 86	....
1884	−17	−17	−20	− 31	−29	−24	− 9	− 1	22	17	2	− 9	− 9	− 21	−26	0	10	32	24	24	27	24	3	27	− 2	−14	− 11	452	+ 10	....
1885	11	18	26	42	15	2	7	11	23	29	12	− 5	− 43	− 48	−28	− 3	− 7	13	25	−17	− 16	− 7	− 1	− 10	−26	−43	− 23	511	+ 69	....
1886	− 4	8	28	17	14	30	7	19	24	9	− 33	−36	− 44	− 25	9	11	2	−10	−44	−22	− 32	−12	−12	− 35	−45	− 9	28	569	+127	....
1887	− 1	− 1	−43	− 72	−73	−26	− 4	22	32	34	22	9	− 47	− 30	51	45	− 6	10	6	26	23	−13	− 8	8	2	−23	− 40	577	+135	....
1888	−41	−63	−32	− 43	−40	−45	− 33	− 23	25	34	64	33	37	32	43	13	− 1	2	3	18	31	31	34	− 10	24	−13	− 57	825	+383	....
1889	−18	− 13	7	− 7	23	4	− 31	− 3	19	36	38	35	43	6	− 1	5	−16	−14	− 9	−21	− 14	21	4	10	41	42	25	480	+ 38	....
1890	27	10	12	− 19	− 7	7	29	50	20	12	− 24	−33	− 2	− 11	− 3	−39	−19	−40	−51	−34	− 7	−21	− 2	4	16	46	33	578	+136	....
1891	− 6	−30	−49	− 26	2	0	14	22	12	− 6	11	−10	− 20	− 13	0	1	−40	−10	− 5	10	42	40	− 5	5	15	2	− 33	429	− 13	....
1892	15	20	0	− 6	− 3	−10	− 12	0	11	20	9	22	13	9	16	−10	− 6	−14	−10	7	11	− 1	1	20	27	− 1	− 10	297	−145	....
1893	−16	− 6	9	17	23	18	4	10	24	23	16	3	0	3	5	10	2	3	10	12	10	−12	−25	− 13	−21	−19	− 29	333	−109	....
Sum	−39	−56	−39	−120	−65	−27	20	157	246	255	139	−57	−127	−179	− 1	12	−95	−51	−64	44	141	82	0	63	−15	−37	−122	442		
D−I	−38	49	− 3	231	9	−68	−292	−434	−705	−514	−264	98	274	264	− 6	106	340	266	309	−76	−207	−73	31	−110	−70	140	230			

of the existence of a system of magnetic poles and heterogeneous distribution. Furthermore the cosmical region between the sun and the earth must be filled with a magnetic radiation as distinct from the electromagnetic field, a fact of profound significance in considering the relations of electricity and magnetism to the constitution of the ether. The meteorological system is under the direct influence of this solar field, and shows itself primarily in the temperatures of the polar regions, and secondarily in the circulations of the air dependent upon them. Other phenomena of this polar field are the solar magnetic storms, the earth currents, and the aurora which is properly the visible vibration of this magnetic radiation in passing through the atmosphere, in variable intensities.

Variations of the Meteorological and the Magnetic Elements in the Annual and the Sun Spot periods.

An extensive compilation of material has been worked out to determine whether the synchronous variations of meteorological and magnetic elements extend to long periods, such as the annual, due to the orbital motion of the earth, and the eleven year period, of which the sun spot frequencies is characteristic. The results are briefly mentioned, as a complete description of the process is not suitable to this paper.

An arbitrary scale was constructed on semi-transparent celluloid, the size of the daily weather map, on which the lines of latitude and longitude are drawn, as well as certain curves more or less parallel to and others perpendicular to the High Pressure Belt of the United States. By means of these meteorological coördinates, the positions of the estimated centers of all the Highs and Lows, as well as the axis of the clearly defined waves (see previous paper) were read off for the years 1882–1893 inclusive. These were separated into northern and southern groups, which were treated independently. The coördinates were condensed and tabulated so as to be collected by years and by magnetic periods, the object being to learn whether such mean coördinates show any variations in the latitude. The accompanying map shows the resulting positions of the mean North and South High, and North and South Low Pressures, respectively, and also the axis of the advancing wave. The North Low and the South High lines are recognized as the axes of Ferrel's Low Pressure belt, which forms a portion of the polar circuit, and the Mid latitude high pressure belt which forms the tropical circuit. The North High track is the average position of the Highs traveling along the polar circuit; the South Low is that of the average position of formation or occurrence of cyclones in the Southern United States. To

these are added the Colorado-Superior, the Texas-Michigan, the Florida-Nova Scotia, and the Mexican branches. On the same map are placed the average position of the wave fronts from the origin, in the annual mean eastward march. The North High and the South Low tracks are in reality abnormal outgrowths of the atmospheric circulation.

The question is, do these tracks in general move in latitude during the sun spot period? The result is that the North Low and the South High belts vary in latitude directly with the solar intensity, being further north at the maximum, and further south at the minimum of the period; while the North High and the South Low belts vary inversely, that is are further south during the maximum of sun spots. This means that an increase of solar magnetic intensity generates the cyclones further south, and causes the anticyclones from the polar circulation to travel to the south. Precisely the same remarks hold true in the annual period.

The Table of Relative Variations in the Meteorological and Magnetic Systems gives the final results of an extensive computation, many details of which will here be omitted. "Movement in Latitude" refers to the average geographical latitude

TABLE OF RELATIVE VARIATIONS IN THE METEOROLOGICAL AND MAGNETIC SYSTEMS.

	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	
Movement in Latitude	----	----	----	----	+ 9	+ 7	+ 24	+ 5	+ 5	− 18	+ 1	− 4	− 15	+ 7	− 3	+ 11	× 1
Movement in Longitude.....	----	----	----	----	+ 53	− 5	+ 9	+ 5	+ 21	− 22	− 8	+ 15	− 31	− 2	− 2	− 38	I × $\frac{1}{2}$
Temperature Amplitudes.....	− 332	− 34	− 48	− 84	+ 30	− 116	+ 82	+ 543	+ 132	+ 187	+ 207	+ 24	− 111	− 10	− 361	− 88	× $\frac{1}{10}$
Mean Annual Temperatures ..	−2·51	−1·19	−1·27	−1·31	−1·26	+0·36	−0·08	+1·38	+1·38	+0·52	+0·75	−0·95	−1·33	−0·63	+0·23	+0·99	I × 10
Reduced to same Amplitude {	----	----	----	----	9	7	24	5	5	− 18	1	− 4	− 15	7	− 3	11	
	----	----	----	----	27	− 3	5	3	11	− 11	− 4	8	− 16	− 1	− 1	− 19	
	− 16	− 2	− 3	− 4	2	− 6	4	27	7	9	10	1	− 6	− 1	− 18	− 4	
	− 25	− 12	− 13	− 13	− 13	4	0	14	14	5	8	− 10	− 13	− 7	2	10	
Mean of Relative Numbers ...	− 21	− 7	− 8	− 9	+ 6	0	+ 8	+ 12	+ 9	− 4	+ 4	− 2	− 13	0	− 5	− 1	
Magnetic Intensity	− 21	− 11	0	+ 3	+ 24	+ 12	+ 14	+ 10	+ 5	− 14	− 8	− 18	− 36	----	----	----	
Sun Spot Numbers	− 18	− 17	− 4	+ 7	+ 10	+ 12	+ 12	+ 6	− 7	− 14	− 17	− 17	− 17	− 2	+ 17	+ 22	

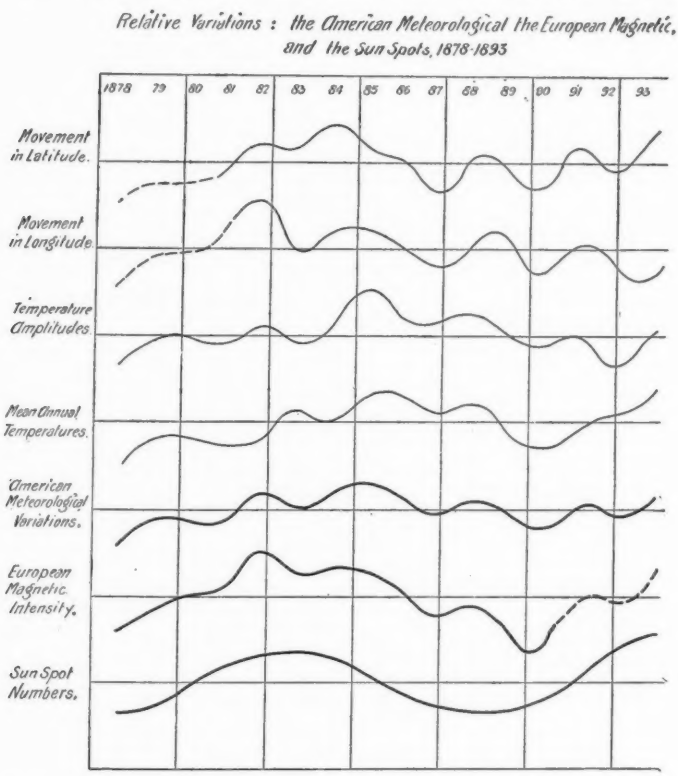
that the four mean tracks, North Low and High, South Low and High, occupy from year to year. The North High and the South Low move in opposite directions to the North Low and South High, the latter moving north with increasing intensity of the magnetic system. The units are 3 miles in latitude, and the range in the sun spot period is about 120 miles. "Movement in Longitude" indicates the variation on the mean eastward drift of the meteorological conditions, taken year by year, and the numbers are here given with the signs inverted. This shows that the increase in eastward movement is for the years of decrease in the magnetic intensity. The physical interpretation of these inversions is at hand, but cannot be explained in this abstract. The unit is 1·37 miles, and the change in movement ranges about 50 miles per day; that is in years when the magnetic intensity of the sun increases, the normal tracks move northward, and the eastward circulation slows down.

"Temperature Amplitudes" relates to the changes in temperature in the 26·68 day periods from year to year. By summing the residuals, already explained, without regard to signs, the amplitudes are obtained, and the sum of these for each year is entered in the table. They are only relative numbers but show the annual changes. The "mean annual temperatures" are derived from 80 Weather Bureau Stations, the annual temperatures being tabulated, summed and the residuals entered, these being the surviving residuals for each year. They are however entered with the opposite signs, and express the fact that the years of an increase of solar magnetic intensity are those of colder temperature in the United States, the explanation of the phenomenon being in harmony with the theory of anticyclonic and cyclonic circulations which I have briefly described in an earlier paper. (Astron. and Astro-Phys., Jan., 1894).

All of these sets of numbers may be treated as merely relative values of one fundamental impulse, namely the solar magnetic field, and hence can be reduced to the same amplitude, the mean of the last relative numbers being a closer representation of the average system than either of these sets alone. It should be noted that on plotting in a diagram, the four sets clearly agree among each other in producing the same curve, even to minute details, the years 1883, 1884, near the crest alone showing some uncertainty in the curves.

"Magnetic Intensity" gives the annual variations of the European magnetic field, as derived for five or more stations, the data referring to the horizontal component, $\sigma = 0{\cdot}000084$ C. G. S., and the unit being the sixth decimal. The sun spot numbers are taken from the Jahrbuch der Astronomie und

Geophysik, III, 1892, with extension to latest observations. These numbers are variations on the mean sun spot number 40, multiplied by the factor $\frac{1}{2}$. The accompanying diagram,


Relative Variations : the American Meteorological the European Magnetic, and the Sun Spots, 1878-1893
1878 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93
Movement in Latitude.
Movement in Longitude
Temperature Amplitudes
Mean Annual Temperatures.
American Meteorological Variations.
European Magnetic Intensity.
Sun Spot Numbers.

plotted on the scale $0{\cdot}5^{mm}$ = unit, gives the comparison of the changes in the American Meteorological System, the European Magnetic Field, and the visible surface of the Sun. The conclusion seems unavoidable that we are here dealing with different portions of a great cosmical system, emanating from the sun and influencing the entire northern hemisphere of the earth, by means of the polar magnetic field. Similar computations for the changes in the meteorological system, its movement in latitude and longitude, and its mean and amplitude temperatures, have been executed for the annual, and the 26·68 day periods, with results in agreement with this important thesis.

The next step in the progress of this investigation is to determine the physical function for the transformation of the energy of the solar magnetic fields, the electromagnetic and the magnetic, into the equivalent heat-energy that exhibits itself in temperature changes. There are many difficulties in the way of this step, but it is hoped that they can be overcome before long.

Formation of Anticyclonic and Cyclonic Circulations.

One of the most remarkable facts regarding the development of the theories of the origin of the Anticyclones and Cyclones of Middle Latitudes, is the excessive weight ascribed to the cyclones. This is perhaps due to a popular interest in the system of winds accompanying Low Areas of Pressure, and to a supposed resemblance between these and the general circulation of the air. Vertical convection currents are said to be the primary source of the movement, and some have seen in the High Areas only the pericyclonic overflow ring, as if these were secondaries to the Lows.

The real order of events in nature may, however, be summarized as follows: The Equatorial Field generates a tropical High pressure, and a sub-polar Low pressure belt, by its distribution of temperature. The continents rearrange these belts so that in winter the small polar circuit surrounding the Icelandic permanent Low, supersedes and predominates, while in summer the great mid-latitude circuit regains its supremacy. Therefore in winter the circulation of the polar circuit is more rapid, being smaller in diameter, the supply comes across the North American Polar regions, and but little from the Pacific; in the summer the slower eastward march in the wider circuit sets in, with the supply from the Pacific. In both cases the movement of air masses is dominated by the varying intensities of the polar magnetic field from the sun, by which the densities of the contents of the unit volume is changed. High Pressure areas are the primary products of these sources of energy, being in part whirled up by the general circulation, and in part the result of reducing the polar absorption by diminution of the cosmical energy on certain dates. Between two successive areas of greater density lies an area of smaller density, where absorption of magnetic radiation has been more vigorous. Under the force of gravity the adjacent sides of the denser areas are drawn together, and meet abruptly along the axis of the low section, in the so-called "trough." The characteristics are that southern warmer air reinforces the high pressure outflow, and transports its charge of aqueous vapor in the current; this meets the colder sheet from the north, in a

calm area or one of variable winds, the vapor contents being cooled by mixture with the lower temperatures and therefore precipitated; at the same time with the counter flow, right hand deflecting forces generate a couple of gyration (See U. S. daily weather maps, Tuesday, March 27, and April 7, 1894, for illustration), which develops somewhere along the axis of encounter a cyclonic whirl, due almost exclusively to horizontal transportation, the vertical movement being a subordinate action; indeed the rapid whirling is a symptom of the lack of vertical motion, the escape of the air at the top of the vertex in the general eastward current being a source of loss of gyratory energy; rainfall accompanies a low area on the side chiefly of greatest cold, or where the oceanic supply can first meet with colder air, and is not a cause of it; tornadoes, thunder storms, the thin band of rain and other phenomena, are secondaries to the counter flow from the two high sheets, are located along the axis, and derive their power from the force of gravity acting on the primary denser high area masses. The synchronism of the magnetic curve is evidently, from day to day, the efficient governor in the succession, this changing in type with the inversion of the system. The difference between the North American and the Siberian systems is a marked increase in the number of cyclones in North America, which cannot be accounted for by geographical conditions. The presence of the magnetic polar system on the American continents is, however, a sufficient source of differentiation. The peculiar system of feeders in the United States is due to the existence of long troughs between successive High areas, along the axis of which the cyclones move eastward and northward; while the Siberian High area, thrown up by the general circulation, is not broken into smaller masses by the magnetic variable intensities. The interplay about the "origin" is that of the discharge of the polar High belt across the Low belt, the tendency of the Pacific High to join the Polar High, the drift of the High areas east, partly along the Low belt, and partly into the southern High, and also between them as if in doubt which system to join. The interplay of these several systems adds to the complexity of the weather of the United States, and renders the art of forecasting very difficult to acquire.

Much light is, however, thrown upon these problems, by the possession of the true solar period of rotation, the form of the intensity curve, and the fact of its sudden reversal at certain times. This has occurred recently, on Dec. 3, 1893, Jan. 21, 1894. Attending these reversals are stagnations of movement, the transition from the polar to the midlatitude circulation, the passage from one hemisphere of the sun to the other, and

apparently some action within the solar nucleus which is not yet understood. For if the periods of direct and inverse temperatures are collected in a table, marked D and I respectively, it is seen that there is a peculiar sequence among them in relation to the sun spot curve. The D and I periods interchange position in the table along with the sun spot variations, the I type following the curve directly, and the D type inversely. What this signifies in solar physics it is not yet possible to say, though it probably has to do with the nature of so-called positive and negative magnetism. Such material needs perfecting to reach its final form, but the clue here presented is so suggestive that it is published as it stands at this time.

DISTRIBUTION OF THE TYPES D AND I IN A SUN SPOT PERIOD.

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1878 ..	**D**	I	I	I	I	**D**	**D**	I	**D**	**D**	**D**	I	**D**	**D**
1879 ..	I	I	**D**	I	I	I	**D**	I	**D**	**D**	**D**	**D**	**D**	**D**
1880 ..	**D**	**D**	**D**	I	I	I	I	**D**	I	**D**	**D**	**D**	I	
1881 ..	**D**	**D**	I	I	I	I	**D**	**D**	**D**	I	I	I	**D**	I
1882 ..	**D**	**D**	**D**	**D**	**D**	I	I	I	I	I	I	I	I	**D**
1883 ..	**D**	**D**	**D**	**D**	**D**	I	I	I	I	**D**	I	I	I	
1884 ..	**D**	**D**	**D**	**D**	**D**	I	I	I	I	**D**	**D**	**D**	**D**	I
1885 ..	**D**	**D**	**D**	**D**	**D**	I	I	I	I	I	I	**D**	**D**	I
1886 ..	I	**D**	I	**D**	**D**	I	**D**	**D**	**D**	**D**	**D**	I	I	
1887 ..	I	I	**D**	I	I	I	**D**	I	I	**D**	**D**	**D**	**D**	I
1888 ..	I	I	I	I	I	I	I	**D**	**D**	**D**	**D**	**D**	**D**	I
1889 ..	I	**D**	I	I	**D**	**D**	**D**	**D**	**D**	**D**	I	I	I	
1890 ..	I	I	**D**	**D**	I	I	I	I	**D**	**D**	**D**	I	**D**	I
1891 ..	I	I	I	I	I	**D**	**D**	**D**	I	I	I	I	**D**	**D**
1892 ..	**D**	**D**	I	**D**	**D**	I	I	I	I	I	I	**D**	I	I
1893 ..	**D**	**D**	I	**D**	I	I	**D**	I	I	**D**	**D**	**D**	I	

Sun Spot Curve.

Temperatures direct **D**, inverted I.

ART. LXII. *Remarks on Colloidal Silver;* by C. BARUS.

1. IN the absence of Dr. E. A. Schneider I wish to say that there does not seem to be any real issue between the recent note of Mr. Carey Lea* and our own work.† It was our endeavor to arrive at new data relative to colloids in general, and colloidal silver was chosen merely as a promising subject for attack. We showed at length that colloidal silver possesses properties which can be explained with reference to the analogous behavior of suspended sediments. Differences neces-

* Carey Lea: this Journal: October, 1894.

† Barus u. Schneider: Ostwald's Zeitschrift: viii, p. 278, 1891; Wied. Annalen, xlviii, p. 327, 1893. Full references to the above and other allied physical questions are there given.

sarily remained as a result of differences in the size of particles in the two cases, the silver being much more finely comminuted. For this reason we can not admit that Mr. Lea's recent experiment is decisive. A similar test had already been made by Prange* and it was repeated by us with the remark that the Tyndall experiment is no valid criterion unless precise statements are made as to the size of particles which just appreciably interfere with optical clearness. In other words the dimensions below which Tyndall's experiment practically fails are here vitally in question, and data for these have not been forthcoming.

Suppose a solid is dropped into an excess of its solvent. In order that the system may become a solution, the disaggregation must at least reach the molecule. In electrolytes it may even go further as is evidenced by Arrhenius's celebrated factor 2. But, under other circumstances, may not the separation stop short *before* the molecule is reached; or conversely, when a precipitate is being formed out of individual molecules, may not the process of growth be arrested in virtue of an equilibrium of forces when the particles formed consist of 2, 10, 100 or even 1000 molecules? To answer affirmatively is to find a home for the family of colloidals, and they will more nearly resemble solutions in proportion as the particles are smaller. Certainly the beam of light is no longer an available criterion, for the whole phenomenon is mapped out on a scale which is small even in comparison with the wave length of light.

2. About a year and a half ago I incidentally made an experiment in connection with certain meteorological questions, which has a precise bearing on the point here at issue. In the endeavor to pass compressed air through a wet porous porcelain septum into water, I was struck by the magnitude of the pressures necessary. Supposing I waited long enough to insure the transpiration of liquid, no flow of gas through the septum occurred for pressure excesses of even above 100 lbs., excepting at isolated points which were obviously the seat of fissures. Now let T be the surface tension of water in dynes per linear centimeter, α the angle of capillarity, r the mean radius of the pores of the septum, and x the pressure of the gas in atmospheres. Then (very nearly) $10^6 x\pi r^2 = 2\pi r T\cos\alpha$, or

$$r = 2T\cos\alpha / 10^6 x$$

If therefore in the above experiment, $x = 8$ atm., $T = 71$ (Everett's tables, p. 50), $\cos\alpha = 1$ (say, for the superior limit is in question),

$$r = 18\times 10^{-6} \text{ cm},$$

* Prange: Rec. des Trav. chim. des Pays Bas, ix, p. 125.

nearly, making the diameter ($2r$) of the pores smaller than the wave length of violet light. Schneider showed however that colloidal silver passes readily through such a septum whereas the alcoholic precipitate fails to do so. The particles are therefore respectively smaller and larger than the diameter* given. If 10^{-8} cm be taken as the order of molecular dimensions, the size in question is at least 1000 times as large, showing the aggregates to consist of the enormous number of 10^9 molecules, at least. There is thus an abundance of room for particles containing (say) 100 molecules to the aggregate, and forming suspensions in water (colloids) in their general aspects hardly distinguishable from true solutions.

It is interesting to ask how great a pressure would force the water out of a septum just large enough to let the particles of the size in question (5×10^{-8} cm) pass. It would take several thousand atmospheres, and it is therefore quite impossible to test finer septa like animal membrane to the extent in question. Nevertheless if the attempt be made to *grade* porous clay septa, prepared by successive vitrifications, by the method given, I dare say that a range of mean diameters of pores could be obtained, sufficient to answer many outstanding dimensional questions† in relation to the colloidal state; but one should be prepared to exert pressures as high as 100 atmospheres.

2. There is another point of view from which colloidal silver invites treatment, this time in the solid state. Dr. Schneider and I interpreted the high degree of insulation which we detected in Carey Lea's metallic mirrors as an instance of the allied behavior of non-coherent metallic matter, in general. Wöhler (quoted by Wernicke) showed this some 50 years ago; but our references were chiefly directed to the recent work of Auerbach ‡ and of Ed. Branly § the latter of whom in particular proved that non-conduction ceased when an electric spark was passed through the column of powder. One therefore readily calls to mind the startling results recently obtained by Oliver Lodge ‖ with his "coherer," and the question is pertinently asked whether solid colloidal silver, swept by a train of electric surges will begin to show increased electric conduction, as it does for instance under the influence of heat.

* By the hydrodynamic method particles smaller then 2×10^{-6} were measured, supposing the method vouched for. Ostwald's Zts., l. c.

† I may here call to mind the allied geological fact that hot water will pass through porous rock in virtue of capillarity, in the face of enormous withstanding steam pressures.

‡ Auerbach: Wied. Ann., xxviii, p 604, 1886.

§ Branly: Phil. Mag., (5), xxxiv, p. 530, 1892.

‖ Lodge: Nature, vol. l, p. 136, 1894.

Oberbeck's* electric work, undertaken in a different direction with a view of showing the occurrence of an allotropic state in Carey Lea's silver has quite failed to convince us. We see no reason for withdrawing the views which we originally expressed (l. c.)

3. At the close of our experiments † we suggested that a field of great promise would be found in the metallic optics of colloidal silver. Work of this kind has since been taken up with success by Wernicke.‡ The change of phase observed on the reflection of light from thin metallic laminæ enclosed between clear media, with the front plate of greater refractive index, is either an acceleration or a retardation, according as the metal is intrinsically coherent or non-coherent. The method is remarkably sensitive and applicable to metallic films so thin as to be quite invisible to the eye. Tested in this way colloidal silver according to Wernicke§ takes rank with bodies which in their ultimate nature are an aggregate of individual particles, however small they may be, or however perfect the mirroring surface which an even distribution may produce. It is this method which is to be looked to for decisive results, not only for silver but for other colloids.

4. Of the two interpretations which may be given of Carey Lea's brilliant discovery, the one originally advocated by Dr. Schneider and myself is to me intensely the more interesting. As an aggregate of excessively fine suspended particles, colloidal silver introduces a whole series of fascinating physical problems, subject to forces which as to their nature are almost tangible. Even in an ordinary case of sedimentation if I write

Muddy water + acid = acidulated water + mud,

the latter body being precipitated, I have a chemical equation in embryo,—an equation‖ which so far as can now be discerned lacks stochiometric precision, but which in its general character is undoubtedly a double decomposition. If the actuating forces be traced, they must lead by slow gradations up to affinity.

Washington, October, 1894.

* Oberbeck: Wied. Ann., xlvi, p. 265, 1892; xlvii, p. 353, 1892;
† Barus u Schneider: Wied. Ann, xlviii, p. 336, 1893.
‡ Wernicke: Wied. Ann., li, p. 448, 1894; lii, p. 515, 1894.
§ Wernicke: l. c. p. 523.
‖ In the same way I picture to myself, the remarkable physical effects produced by traces of foreign admixtures in metallurgy.

Art. LXIII.—*The Duration of Niagara Falls;* by J. W. Spencer.

[Read before the meeting of the American Association for the Advancement of Science, Aug. 20, 1894.]

Contents:

1. Conjectures as to the Age of Niagara Falls.
2. Modern Topography.
3. Geology of the District.
4. Ancient Topography and the Basement of the River.
5. Discharge of the Niagara River.
6. Modern Recession of the Falls.
7. Sketch of the Lake History and the Nativity of Niagara River.
8. Episodes of the River and the Duration of Each. Age of the Falls.
9. Confirmation of the Age of the Falls by the Phenomena of Terrestrial Movements.
10. Relationship of the Falls to Geological Time.
11. End of the Falls.
12. Conclusions.

1. *Conjectures as to the Age of the Falls.*

About the year 1760, Sir William Johnson acquired possession of Niagara Falls, and from that time its recession impressed itself upon the few observers, so that when Andrew Ellicott made the first survey of the chasm, shortly before 1790, he was informed that the cataract had receded twenty feet in thirty years; whereupon he concluded that its age was 55,440 years.* Bakewell's estimate, in 1830, reduced its duration to about 12,000 years.† According to Lyell, in 1841,‡ the Falls was about 35,000 years old, and this conjecture was generally accepted until a few years ago. The first steps taken towards the determination of the age of the falls were those to ascertain the rate of actual recession. In 1842, Prof. James Hall triangulated the cataracts;§ in 1875,‖ the Lake Survey; in 1886,¶ Prof. R. S. Woodward; and in 1890,** Mr. Aug. S. Kibbe repeated the measurements. In 1819,†† the International Commission surveyed the river, and showed that the apex of the cataract was very acute, yet it does not appear that the measurements could be compared with the later surveys made for the determination of the rate of reces-

* "Journal of William Maclay," Appletons, 1890.
† Cited in "Travels in North America in 1841," by Sir Charles Lyell, vol. ix, p. 27.
‡ The same.
§ "Natural History of New York," Part IV, vol. iv, p. 184.
‖ Lake Survey Chart.
¶ Report of the meeting of the Am. As. Ad. Sc. in Science, Sept., 1886.
** 7th Rept. Com. State Res. Niag., 1891.
†† Printed by the U. S. Lighthouse Board.

sion. The four surveys naturally give data for superseding the earlier estimates, and if the mean rate of retreat of the falls during 48 years, be taken, its age would appear to be 9,000 years. The conjectures of the older geologists have been set aside by recent writers who have endeavored to reduce the age to 7,000 years by using the maximum rate of measured recession. Substituting a measured rate of retreat for one purely assumed was a step in the right direction, but without knowing it, the later writers were farther astray than the earlier, for they neglected to take into account the changing episodes of the river, which was not known to the earliest observers. Only one other geologist besides myself has called attention to the *varying* forces which have made the Niagara *cañon*,—and this is Mr. G. K. Gilbert,* by whom and the writer the principal phenomena affecting the history of the river have been discovered. The last question which had to be determined before a computation of the age of the falls could be undertaken was the approximate amount of work accomplished by the river during each of the episodes in its history. This I was able to estimate last fall.

2. *Modern Topography.*

For distance of 19 miles from Lake Erie (573 feet above tide), the Niagara peninsula is a plain, with slight undulations, rising from 15 to 30 or 40 feet above the lake. But three features are notable: (*a*) a drift ridge trending westward from the falls and surmounted by a beach (L, fig. 8) rising to 114 feet above the lake, with a knob 30 feet higher, at Drummondville; (*b*) at the outlet of Lake Erie, the river cuts through an escarpment of Devonian limestone, which there rises to about 30 feet; and (*c*) at a point about a mile north of the site of the falls there is another limestone ridge here named William Johnson's ridge in honor of the first settler (*e*, *e*, fig. 1) with an elevation of 40 or 50 feet. Between these two rocky ridges is the Tonawanda basin. From the northern margin of the plain, the escarpment suddenly descends about 240 feet to a lower plain which extends eight miles to the shores of Lake Ontario (247 feet above the sea). Upon leaving Lake Erie the river channel is only a quarter of a mile wide but reaches a depth of 48 feet. After passing the Devonian escarpment, the river is broad, even a mile and a half above the fall, with a depth of from 1 to 16 feet. The cañon is about 36,500 feet

*Mr. Gilbert writes thus: "You are aware that I am everywhere quoted as estimating the age of the river (Niagara) as about 7,000 years. It was partly to dispel this impression that I wrote . . . . In point of fact I have made no estimate and my opinion, so far as I have one, is that the age of the river is much greater than 7,000 years."

long and varies from 900 to 1400 feet in width (see fig. 1 and sections). After the river issues from the gorge its width is about a half a mile, and the depth reaches to 96 feet, or 94 feet below the surface of Lake Ontario. In the cañon, three quarters of a mile below the site of the falls, the river has a depth of 189 feet, at a point where the surface is about 105 feet above the lower lake. That the upper part of the walls of the cañon are vertical should be emphasized.

3. *Geology of the District.*

The geology of the district is too well known to need description, but the measurements had not been made which could be used in determining the varying character of the work performed by the river; accordingly I made the following sections and those illustrated in figures 3, 6, 7, 8, 9, 10, 11.

	At Falls.		Whirlpool		Devil's Hole.		N. Cath. Col.		End of Gorge.	
	Feet thick.	Ft. ab'ye L. Ont.	Feet thick	Ft. ab'ye L. Ont.	Feet thick.	Ft. ab'ye L. Ont.	Feet thick.	Ft. ab'ye L. Ont.	Feet thick.	Ft. ab'ye L. Ont.
Pleistocene in depressions and on ridges	160	440	40*	340	----	----	----	----	----	----
Niagara limestone	55	280	65	300	{30}	340	{35}†	340	{15}†	340
Crest of Falls	----	270	----	----	{60}†	----	{40}	----	{25}	
Niagara shale	60	225	65	235	----	250	60	265	75	300
Clinton limestone	15–20	165	20	270	----	----	20	205	15	225
Bands of shale, limestone and sandstone at base	20–15	----	----	15–20	----	----	20	----	20	
Surface of river	----	110								
Medina shale	25	----	25	----	----	----	----	----	20	
sandstone‡	5–10	100	8	105	----	----	----	----	5	170
shale	30	----	30	----	----	----	----	----	25	
sandstone	20	60	20	60	----	----	----	----	20	140
shale to lake level	40	----	40	----	----	----	----	----	120	

The plain between the escarpment and Lake Ontario is underlaid by a great thickness of Medina shales thinly covered with drift and lacustrine deposits. The flat country, between the head of the rapids above the falls and the Devonian escarpment near Lake Erie is underlaid by shaly rocks of Onondaga age. The southward dip of the strata from the end of the gorge to the Devil's hole (9,700 feet distant, at the mouth of Bloody run) is 40 feet; thence to the whirlpool

* Drift on west side, rocks on east side of gorge.
† The upper figures relate to rocks in river terrace; the lower in walls of gorge.
‡ Both the Medina sandstone and shales vary in thickness.

(8,500 feet) 26 feet; and from there to the falls (15,000 feet in a direct line) only 10 feet, or almost horizontal.

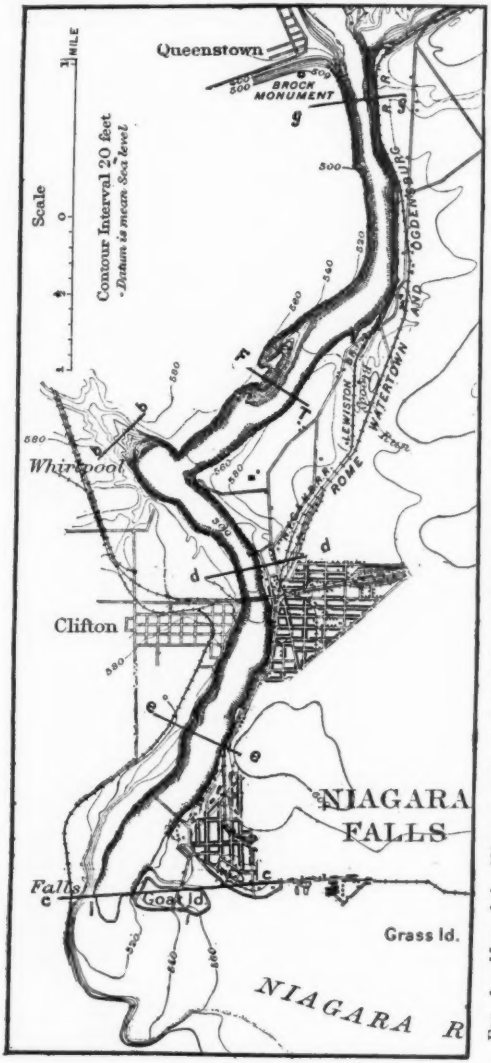


Fig. 1.—Map of the Niagara *Cañon* (U. S. Lake and Topographic surveys) showing its variable width and the position of the cross sections.

4. *Ancient Topography and Basement.*

In the numerous writings upon the Niagara river one ancient topographic feature has been overlooked and another exaggerated into importance which it does not possess. The ancient drainage of the Erie basin was not by way of the Niagara but by a channel forty miles to the west.* Even at the end of the Lake Erie the borings show old channels deeper than the floor of the river across the Devonian escarpments.† The feature overlooked is the Tonawanda valley, a mile and a half in width, extending from the rapids above the falls to the Johnson ridge. Its basement is 80 or 90 feet below the northern barrier of Johnson's ridge. The rocky subsurface of Goat Island was part of the ancient floor (see fig. 11). This depression is part of the ancient Tonawanda basin, which is now filed with drift (see fig. 8). The gorge through Johnson's ridge is modern with vertical walls, but half a mile to the west it falls away and the wells reveal the continuation of the Tonawanda depression extending northward. It is again made known by a well half a mile west of the whirlpool (*w*, fig. 3), in the line of the extension of the St. David's valley. This forms an embayment one and a half miles wide and only three-quarters of a mile deep in the face of the Niagara escarpment. The modern river is simply crossing a portion of the old Tonawanda basin in the vicinity of the falls, and consequently it has here much less rock to excavate than through and north of Johnson's ridge.

The other feature is the imaginary whirlpool—St. David's valley, supposed to have been the old course of the river.

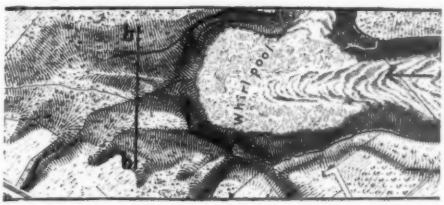


FIG. 2.—Map of the whirlpool ravine; *bb*, position of section (fig. 3).

Above and below the whirlpool alike, the gorge is of recent date as may be seen by the vertical walls shown in the several sections. The whirlpool ravine has sloping V-shaped bound-

* "Origin of the Basins of the Great Lakes," Q. J. G. S. Lond., vol. xlvi, p. 523, 1890, and "Notes on the Origin and History of the Great Lakes," Proc. A. A. A. S., vol. xxvii, 1888.

† "The Life History of Niagara," by Julius Pohlman, Trans. Am. Inst. Min. Eng.

aries in its higher portion, which is an antique structure. The depression is so obstructed with drift, that gives rise to landslides that the old topography is much obscured. Yet a little stream has removed the fallen earth and exposed a natural section of Clinton limestones, which cross the valley at an elevation of 115 feet above the surface of the whirlpool, or 160 feet above Lake Ontario, with Niagara shales showing for at least 20 feet higher. Thus the rocky barrier across the ravine is not less than 240 feet above the bottom of the cañon in the whirlpool. This barrier in the ravine is illustrated in fig. 3, which should be compared with figures 9 and 10, in order to appreciate the insignificance of the whirlpool ravine.*

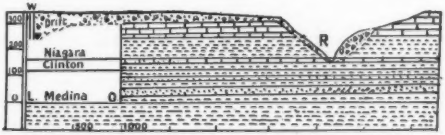


FIG. 3.—Section across the whirlpool ravine, located at *bb*, fig. 2; W, well; R, stream.

The form of the whirlpool cauldron requires explanation. At Mr. Shepherd's house, a short distance west of the whirlpool, there is a well 90 feet deep without reaching rock (*w*, fig. 3) and this shows the absence of Niagara limestones to a depth of more than 50 feet below the surface rocks of the western wall of the whirlpool. At that point the limestones rise 40 feet higher on the eastern side of the river than on the western, but the depression was leveled up with drift. Thus it appears that at this point the Niagara river took possession of the eastern side of a drift-filled valley (Tonawanda—St. David's), and the whirlpool ravine was a little tributary to it. When the falls had receded to the whirlpool and penetrated the rocky barrier, the currents were able to remove the filling of the buried ravine, and this gave rise to the form of the cauldron, which deepened its basin to lower levels by the currents of the river acting upon the underlying soft shales, with the landslides obscuring the older features. It is evident that there was no preglacial Niagara river.

The Niagara river crossed the broad shallow depression of the Tonawanda drainage, at the falls and that adjacent to the whirlpool on a basement of drift, but elsewhere generally on hard limestones. Out of both of these materials, terraces were carved thus marking the old river level, before it sunk within the chasm.

* In Rept. of meeting of Am. As. Ad. Sc. in Science, Sept., 1886, it is noted that Prof E. W. Claypole found rocks in the ravine, without giving any details in explanation. Since this paper has been in type, Prof. James Hall informed me that Prof. J. W. Powell and himself had also seen the occurrence of the rocks, but no notice has been printed. The error has been even recently repeated by a writer in "Nature."

5. *Discharge of the Niagara River.*

The corps of Engineers U. S. A., made the measurements of the outflow of the Great Lakes between June 27th and Sept. 17th, 1868.* That of Lake Huron was 216,435 cubic feet per second; and of Lake Erie for the first part of the season, 304,307 cubic feet, and 258,586 feet for the second part. From these figures, I have taken the maximum proportional discharge (as the volume is variable) of Lake Erie, which is found to gather $\frac{3}{11}$ of the total drainage of the Niagara River but the mean discharge is less than $\frac{3}{14}$. This is an important factor in the following computations.

6. *Modern Recession of the Falls.*

The four surveys illustrated in figure 4, show the modern recession of the horseshoe cataract. During 48 years, 275,400 square feet fell away. The mean width of the adjacent portions of the gorge (as opposite Goat Island) is 1,350 feet. Thus the mean recession would be 4·175 feet a year. The American falls have undermined 32,900 square feet of rock which gives a mean rate of 0·64 foot a year. But the rate is not uniform. In 1819, the crest of the Canadian fall was very acute, it had

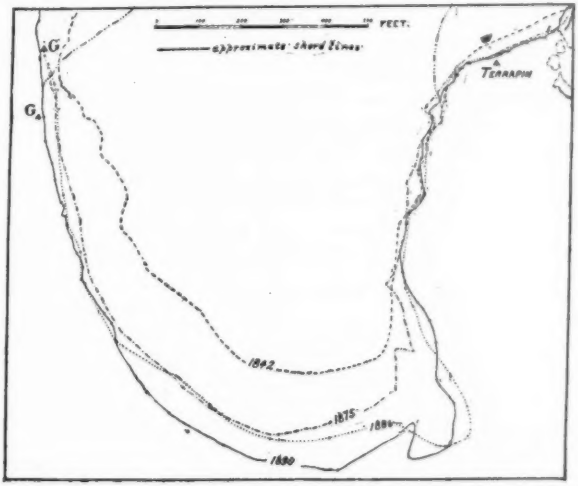


FIG. 4.—The four surveys of the Canadian Falls showing the retreat of the cataract (in which some inaccuracies are apparent). (Kibbe).

become quite obtuse in 1842, acute in 1886, but it was broadening out again in 1890; thus there are cycles of slow and rapid retreat.

* Report of Chief of Engineers for 1869, p. 582.

The measured recession has probably obtained, since the cataract cut its way through Johnson's ridge, for beneath the Tonawanda basin the limestones have a thickness of only 45–55 feet as the upper 90 feet had been removed in pre-Pleistocene times. The capping limestone in Johnson's ridge was 140 feet thick. To the north the thickness was reduced. Along those portions of the chasm where the limestone is heavier and the gorge narrower than in the pre-glacial depression, the stronger arches must have arrested the maximum rate of retreat, and on this account, I have reduced the measured mean rate of recession by an estimated amount of ten per cent, or to 3·75 feet a year for the recession of the falls from the end of the cañon to Johnson's ridge, under conditions of the modern discharge and descent. The mean descent of the river was from the plain now at 340 feet above Lake Ontario; but whilst passing the rapids of Johnson's ridge, 25 feet must be added to the declivity of the river. After the basin behind the ridge was reached, the water plain was reduced to about 320 feet including 50 feet of descent above the falls in the form of rapids. The surface of the country has been deformed since the commencement of the cataract by a northward terrestrial uplift to the extent of 12 or 15 feet divided throughout the length of the gorge where, as seen in the cañon, the character of the different strata is remarkably uniform except in the described depressions, across Johnson's ridge, and at the end of the chasm where the capping limestones were much thinner but partly compensated for by the greater prominence of the hard Clinton and Medina layers.

The following computations are based upon the mean rate of recession modified by the variations in the descent of the waters and their changing volumes, which have been discovered in the geological investigations of the Great Lakes.

7. *Sketch of the Lake History and the Nativity of the Falls.*

This outline is taken from the chapters on the Lake History noted at the foot of the page.* At the commencement of the Lacustrine epoch, Warren water covered most of the Lake region, and Forest Beach was its last strand. Afterwards the waters sank 150 feet, thereby dismembering Warren water into Algonquin Lake (confining it to the basins of Superior, Michi-

* "The Iroquois Beach, a chapter in the History of Lake Ontario," Trans. Roy. Soc. Can. 1889, p. 132. "Deformation of the Iroquois Beach and Birth of Lake Ontario." this Jour., vol. xl, p. 443. 1890. "Deformation of Algonquin Beach and Birth of Lake Huron, Id," vol. xli, p. 12, 1891. "High Level Beaches in the region of the Great Lakes and their Deformation." Id., p. 201. "Deformation of the Lundy Beach and the Birth of Lake Erie," Id., vol. xlvii, p. 207, 1894. All by J. W. Spencer. "The History of Niagara River," by G. K. Gilbert, Six. Rep. Com. State Res. N. Y., 1891.

gan and Huron) with an outlet by way of the Ottawa valley, and Lundy Lake (occupying the Erie basin and) extending into the Ontario valley. These two bodies of water appear to have had a common level as if connected in some way across the Ontario basin, but their northeastern extensions are not known and involve unsettled questions that do not effect the history of Niagara. Again the waters were lowered so that the Niagara River emptied the overflow of the Erie basin, without a fall into the Ontario valley. This condition did not last long, for the waters sank to a level (Iroquois Beach) of 300 feet below the Lundy (and also Algonquin) plain and the falls commenced their descent with the waters of the Erie basin alone. The subsidence was accompanied by slight pauses, but waters remained for a long time at the level of the Iroquois beach, which is now about 135 feet above Lake Ontario at the end of the gorge. Again the waters subsided to the level about 80 feet beneath the present level of the head of Lake Ontario and thereby lengthened the river to 12 miles beyond the end of the chasm. At this time the descent of the river after passing the rapids at Johnson's ridge was 420 feet. By the continued northeastern terrestrial elevation the waters of the Huron basin were turned from the Ottawa drainage into the Erie basin, whose northeastern rim was elevated so as to flood the lake. Later, the waters at the head of Lake Ontario were raised 80 feet to the present level. This differential movement was at zero at the head of Lake Erie; 2·5 feet per mile in the Niagara district; 4 feet northeast of Lake Huron, and 5 feet per mile at the outlet of Lake Ontario.

At the nativity of the Niagara River, there was no fall. A little later in the Iroquois episode the falls were very much like the modern American cataract both in height and volume, but afterwards it increased in magnitude and went through the changes noted later.

8. *Laws of Erosion.*

When erosion is considered from a theoretical point of view and the whole energy of the water is supposed to be expressed in the erosion, it varies as the mass of the water into the square of the velocity (wv^2). Hence for a given river increase of the amount of its water or increase of the velocity along its course should be expressed by greater erosion. But erosion is not the only expression of the theoretical value of the energy of the river. Again it is well known that the more rapid the descent of the stream the more the erosive effects are expended on the floor of the channel, in deepening and forming U-shaped valleys or gorges. On the other

hand, the reduction in the slope causes the channel to become broader—a principle which has an important bearing in this study. While the observations are imperfect owing to the variable conditions of erosion, still the attempt to ascertain the duration of the different episodes is the only natural sequence to the measurements of the modern recession of the falls, and it gives approximate results, for without considering the changing episodes the rate of recession is of no geological interest. But this study may lead to further detailed investigations.

8. *Episodes of the River and the Duration of each—Age of the Falls.*

First Episode.—From the history of the lakes and the river, we learn that the early falls cascaded from the brow of the escarpment to the level of the Iroquois beach 200 feet below, with the Erie drainage only $\frac{3}{11}$ of the total discharge of the upper lakes). There is no indication that the Erie rainfall was greater at that time than now. The length of the chasm excavated during the first episode is found in the data fur-

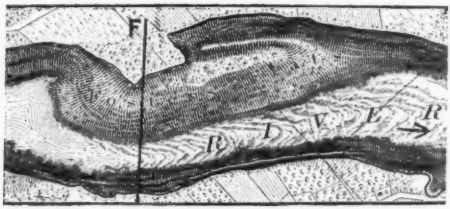


FIG. 5.—Map of the gorge at Foster's flats; F, location of the cross section fig. 6.

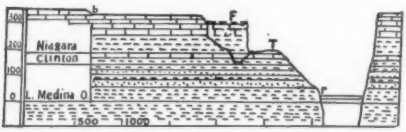


FIG. 6.—Section of the george at Foster's flats (FT, fig. 1). Platform (F) of the old river floor projecting into the cañon. Its section is shown in broken shading but with ravines descending from both sides of it. T, rock terrace surmounted by huge blocks of Niagara limestones; *b*, original river terrace; *r*, surface of river; L. O., surface of Lake Ontario. Bottom of river about 80 feet below the surface of the lake.

nished by the study of Foster's flats. Their location is shown at F, figure 1, and the structures are further illustrated in figures 5 and 6.

The terrace (T) represents the former level of the river (about 190 feet above Lake Ontario). It is the only feature of the kind in the cañon. It is about 50–60 feet above the Iroquois level to which the river descended. Thus the slope of the earlier and smaller streams was about half as great again as the modern river over the rapids at this locality. The youthful river was broad and shallow, like and of about the same magnitude as the modern American channel and falls, acting evenly over the whole breadth and receding at about the same rate. The remnant of the platform shows how far the fall had receded before the physical change which threw the current to the eastern side of the channel. This change could be effected by increasing the height of the falls which would favor the deepening of the chasm at the expense of the width, especially as the lower rocks are mostly shale. This change of breadth from a wide and shallow to a narrow and deep channel is shown along the lower part of the cañon and is illustrated by the contracted channel at the bottom of the cañon in a section just above the end of the gorge (fig. 7).

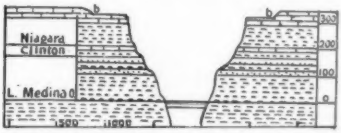


FIG. 7.—Section half a mile from the end of the cañon (*gg* fig. 1); *bb*, terraces of river at the original level; L. O., level of Lake Ontario; bottom of river about 80 feet below the surface of Lake Ontario.

As the changing conditions were gradual, I have placed the close of the first episode at the time when the falls had reached the foot of the terrace (B fig. 8), which is 11,000 feet from the end of the chasm. Varying the rate of recession for the different conditions of height and volume, acting under a general uniformity, the time needed to excavate the immature cañon as far as Foster's terrace is found to be 17,200 years.

Second Episode.—The subsiding of the waters at the end of the first episode, which concentrated the stream upon the side of the channel amounted to 220 feet, thus increasing the descent of the water to 420 feet, with the lake receding twelve miles, and adding this length of shaly rocks to be removed. The increased descent gave rise to new cascades over the hard Clinton limestones (*c* and *d*, fig. 8) and Medina sandstones (*h*, fig. 8) at the end of the cañon, after the shales between it and the lake had been somewhat reduced in height. A modern repetition of three such cascades over the same series of rocks may be seen along the Genesee River near Rochester. Under this condition the upper cascade receded by itself past Foster's ter-

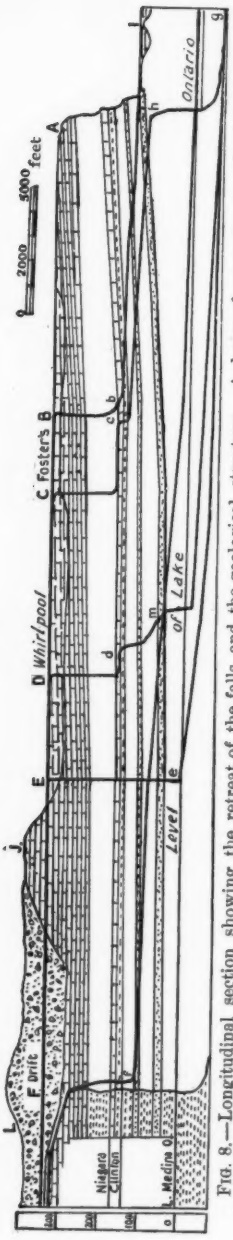


FIG. 8.—Longitudinal section showing the retreat of the falls and the geological structure. A, brow of escarpment and original site of falls; I, Iroquois beach and level of that water; B *b* I, chasm at the end of the first episode; C *e h g*, falls retreating in three cascades, but from *h* to *g* the slope was extended over a distance of 12 miles beyond the escarpment; D *d m g*, position of cataracts at the end of the second episode; E *e g*, development of gorge at the end of the third episode; F, present site of falls, and F *m g*, the modern cañon; *g*, level of the lowest stage of water in the river history; L, Lundy beach capping the drift; J, Johnson's ridge. Broken shading about whirlpool shows occurrence of drift on west bank only with rock on the eastern; block shading represents limestone; dotted, sandstone; broken lines and unshaded portion, shales. Bottom of river 80 feet below present surface of Lake Ontario, as shown in figure.

race, a distance of 3,000 feet. Thus closed the first stage of the second episode. After passing Foster's flats the chasm shows the effects of a greatly increased force, for the gorge is again widened with the terrace below washed away. As no change in the total height occurred about this time, the magnitude of the erosion indicates an increased discharge, which was produced by the turning of the waters of the Huron basin and adding them to the Niagara drainage. The effects of the greatly increased volume of the water were to widen the chasm and cut away part of Foster's platform, but leaving enough to tell the history. The upper falls were not joined by the more rapidly retreating lower cascades until after the whirlpool was passed, for the evidence of the upper water-level is left in the deposits of river gravels at an elevation of 190 feet on the northern side of the whirlpool ravine, which would not have been the case if the river were at a lower level after cascading over one united falls. Just above the whirlpool, the chasm becomes narrow, and here I close the second stage of this episode of three cascades. The length of this section of the gorge (from C to D fig. 8) is 7,000 feet. By considering the proportional amount of work accomplished during the elongation of the chasm, the deepening of the gorge left

at the close of the first episode, and its extension 12 miles lakeward (the mean depth of shales removed from eight miles was 180 feet, and from four miles, 60 feet), and applying the laws of erosion, I have found that the first stage required 6,000 years and the second 4,000 years; or the duration of the second episode was 10,000 years.*

Third Episode.—The narrowest portion of the gorge extends from the whirlpool for a distance of 4,000 feet as is shown in figure 9 and on the map in fig. 1. The various sections (figs. 6, 7, 9, 10, 11) should be compared.

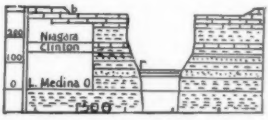


FIG. 9.—Section across the narrows just north of the railway bridges (*dd*, fig. 1) *b*, original bank of the river; *r*, surface of the river; L. O., level of lake; floor of cañon 80 feet below lake level.

This is the site of the whirlpool rapids. My explanation of this narrow chasm, without any increased thickness of the limestone capping over the shaly bed is that the whole force of the falls descending 420 feet was concentrated in one cataract with a rapid of an additional height of 25 feet descending in front of Johnson's ridge. Thus the force engaged in undermining the limestones was exhausted in the recession of the falls by deepening the gorge in place of broadening it, a process more strongly brought out by contrast with the sections of the cañon, immediately above (fig. 10) and below (fig. 6) which are half as wide again. Such result is in accordance with the common observations that increased declivity causes the channels to be deepened, and decreased slope accelerates the widening of the channel as is shown in the section near the end of the gorge (fig. 7). The computation of the time of the retreat of the falls across this section is a simple problem, as the fall of water amounted to 420 feet in place of 320 of the present day, and the volume was the same. Under these conditions the duration of this episode was 800 years.

Fourth Episode.—This is characterized by the rising of the waters in the Ontario basin so as to bring the lake to the pres-

* One method considers only the recession of the upper one of the retreating falls (descending 150) feet during the two stages of this episode. Owing to the prevalence of limestones in the upper section, the computation would appear to be an under estimate. Another process is based upon the excavation of the new portions of the chasm to the full depth of 420 feet, and adding to the components the time required to deepen the gorge of the first episode and extend the cañon to the lake—the amount of work being considered in terms compared with the full depth of excavation in the chasm.

ent level, 320 feet below the rapids above the falls. The commencement of the work of this epoch was taken where the cañon suddenly became broad at the head of the whirlpool rapids, a phenomena explained by the force of the river being vertically diminished and latterly increased—the converse to the conditions of those of the third episode. At first the rocks

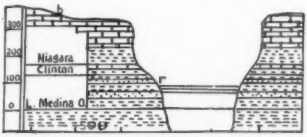


FIG. 10.—Section across the gorge at Johnson's ridge (*ee*, fig. 1); L. O, level of Lake Ontario; *r*, surface of river; *b*, original bank of river; bottom of river 80 feet below surface of the lake.

in Johnson's ridge offered great resistance on account of the increased thickness of limestones, nevertheless the lateral erosion gained the ascendancy over the vertical. The section through Johnson's ridge is 5,500 feet long, and with the laws of erosion the time necessary for the falls to retreat through it would be about 1,500 years—thus would end the first stage of the last episode. The last stage is the modern, or that since the cataract reached the Tonawanda basin south of Johnson's

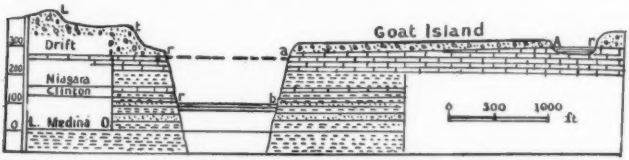


FIG 11.—Section across gorge 1,000 feet north of the Horseshoe falls (*cc*, fig. 1 L, Lundy beach to the west; *t*, terrace with sandy face; *ra*, surface of river at crest of falls; *rs*, ditto below falls; A*r*, ditto of American falls; L. O., level of Lake Ontario. Bottom 80 feet below lake surface.

ridge, whose rocky floor, generally speaking, is about 80–90 feet lower than that on the ridge (see fig. 8); yet the cañon just north of the ridge is only 250 feet wider than through that barrier. The drift filling the basin offered but little resistance to the recession of the falls and accordingly the rate of retreat has been comparatively rapid along this section of the river, which is 6,000 feet long. Consequently its age is about 1,500 years. Thus the duration of the fourth epoch has been 3,000 years.

Age of Falls.—Allowing 1,000 years for the duration of the river before the advent of the falls,—for that its commencement was not characterized by a cascade is shown by the terraces on the edge of the escarpment and at the deserted mouth

of the infant river,—and adding the duration of the four episodes, which have been calculated at 31,000 years, the age of Niagara River would be 32,000 years; and the date that the Huron drainage turned from the Ottawa valley to the Niagara was 7,800 years ago. In order to reduce the errors in reading the means of erosive effects, the component stages have been taken to as great a degree of accuracy as practicable. In the changes of level, the error would suggest itself to me as on the side of shortening the time; and there is no evidence that a much greater rate of recession than now has occurred other than that already made use of; also I have used the maximum discharge of Lake Erie. Consequently I am led to conclude that the present study has set forth the history and has compensated for possible over-estimates in degrees of hardness, and fairly represented the age of the falls, which is very near that of Lyell's conjecture. There is considerable cumulative evidence adduced from the history of the lakes to strengthen confidence in the methods pursued in this investigation. Let us see.

9. *Confirmation of the Age of the Falls by the Phenomena of Terrestrial Movements.*

In the deformatory elevation of the Niagara district, the Johnson ridge was raised 24 feet above the Chicago divide, between the Michigan and Mississippi waters, and did cause a rise of the waters in the lakes to the point of overflowing, but the ridge was incised by the retreating falls in time to prevent the change of the lake drainage. By the simplest case of division we have seen that Johnson's ridge was completely cut through only about 1,500 years ago. Allowing two or three feet of water to have been on the Chicago divide (covered with silt) and as much more for error, we find that the differential elevation of the Niagara district becomes a local absolute uplift of about 1·25 feet a century. The equivalent rate of elevation northeast of Lake Huron is 2 feet and at the outlet of Lake Ontario 2·5 feet a century. This average is that of episodes of activity and repose during 1,500 years. Applying the time ratio to the amounts of deformation we shall obtain the results given below in a form for comparison.

The rise of the Algonquin beach of the Huron basin, between the present outlet of the lake and the former outlet at Lake Nipissing, amounts to 660 feet,* about 560† of which

* Elevation south of and adjacent to Lake Nipissing determined by Mr. F. B. Taylor.

† The waters of both Lundy and Algonquin lakes were lowered about 100 feet before the beginning of the Niagara river; this being apparent and local, produced by a pre-Iroquois uplift of about half a foot per mile, thus raising the northeastern extensions of the beaches.

have been raised up since the birth of Niagara Falls. Of this latter amount about 130 feet have been lifted since the waters were turned into the Niagara drainage. Again we get some proportions.

The ratios of the deformation of the Lundy and Iroquois beaches are about the same, and we have the Lundy beach differentially raised 160 feet in the Niagara district, and the Iroquois beach deformed to 370 feet near the outlet of Lake Ontario (compared with the level at the head of the lake) since the close of the Iroquois episode. And here there are data for comparison. These figures have been mostly taken from the papers already cited. Compiling the results derived from all these data, it appears that:

A.	The time which has elapsed since the Iroquois episode, or the end of the first episode of the falls is :		
	(1) From the computations given	13,800	years.
	(2) From the date of deformation recorded in the Iroquois beach*	14,800	"
	(3) From the deformation recorded in the Lundy beach†	12,800	"
	Mean result	13,800	"
B.	(1) Computed time since the Huron waters turned into the Niagara	7,800	"
	(2) From the proportional deformation of the Algonquin (N.E.) outlet compared with the computed age of the river‡	7,400	"
	(3) From the proportional deformation of the Algonquin uplift§	6,500	"
	Mean result	7,233	"
C.	(1) Computed age of Niagara river	32,000	"
	(2) From the rate of deformation of Algonquin beach since the commencement of Niagara river‖	28,000	"
	Mean result	30,000	"

These computations were originally made not to seek for favorable evidence but to discover discrepancies, for I did not expect that the date had been correlated with sufficient accuracy; but the several results agreeing so closely in spite of the unavoidable inaccuracies, seem to me to comfirm the general correctness of the determinations of the phenomena and the methods of computation.

* A differential rise of 370 feet at the outlet of Lake Ontario divided by 2·5 feet a century.

† A rise of 160 feet in the Niagara district divided by 1·25 feet a century.

‡ $\frac{120}{660}$ of 32,000 years.

§ $\frac{13}{23}$ of 28,000 (see next note).

‖ Rise of 660 feet in the Algonquin beach less 100 feet before the birth of the Niagara at the rate of 2 feet a century.

10. *Relationship of the Falls to Geological Time.*

All attempts to reduce geological time to terms of years are most difficult, but the Niagara river seemed to be an easy chronometer to read, and yet we see that utterances even this year are vastly farther from the mark than those made fifty years ago—the clock had not kept mean time throughout its existence. After this attempt at regulating the chronometer, investigators will doubtless carry the determinations to greater accuracy, but for the present I can offer this geological compensation. The Niagara seems a stepping stone back to the ice age. What is the connection between the river and the Pleistocene phenomena?

The Lake epoch is an after or late phase of the Glacial, and Niagara came into existence long subsequent to the commencement of the lakes. If we take the differential elevation of the deserted beaches, and treat them as absolute uplifts in the Niagara district, with the mean rate of rise in the earlier portion of the lake epoch as in the later, then the appearance of Warren water in the Erie basin was about 60 per cent* longer ago than the age of Niagara river; or about 50,000 years ago. The earlier rate of deformation was not greater than that during the Niagara episode as shown by the deformation of the beaches but it may have been slower, so that from 50,000 to 60,000 years ago Warren water covered more or less of the Erie basin. Before the birth of Niagara river, by several thousand years, there was open water extending from the Erie basin far into the Ontario and all the upper lakes were open water with a strait at Nippissing, but the northeastern limits are not known, and although they do not affect the age of Niagara, yet they leave an open question as to the end of the ice age, in case of those who do not regard the advent of the lakes as its termination. Certainly, if not before the Iroquois episode, at its close the ice age had ended so far as the whole lake region and St. Lawrence valley is concerned; and the end of the Iroquois episode was about 14,000 years ago. To attempt to place the end of the ice age at either 50,000 or 14,000 years ago, or between, would be to base the conclusions upon opinions and conjectures not so far settled by the incompletely written history of the lakes, whose age in terms of the falls may be inferred. The determination of the end of the ice age will be in terms of the lake history.

* The beaches show an elevation in the Niagara district (accompanied by deformation) amounting to 940 feet above tide, of which 573 feet have been raised since the birth of the Niagara river.

11. *End of the Falls.*

As has already been noted, the falls was in danger of being ended by the turning of the waters into the Mississippi, when the cut through the Johnson ridge was effected. With the present rate of calculated terrestrial uplift in the Niagara district, and the rate of recession of the falls continued, or even doubled, before the cataract shall have reached the Devonian escarpment at Buffalo, that limestone barrier shall have been raised so high as to turn the waters of the upper lakes into the Mississippi drainage by way of Chicago. (An elevation of 60 feet at the outlet of Lake Erie would bring the rocky floor of the channel as high as the Chicago divide, and an elevation of 70 feet would completely divert the drainage. This would require 5,000 or 6,000 years at the estimated rate of terrestrial elevation. It would be a repetition of the phenomena of the turning of the drainage of the upper lakes from the Ottawa valley, into the Erie basin.

12. *Conclusions.*

The computation of the age of the Niagara river,—based upon the measured rate of recession during 48 years; upon the changing descent of the river from 200 to 420 feet and back to 320 feet; and upon the variable discharge of water from that of the Erie basin only, during three-fourths of the life of the river, to afterwards that of all the upper lakes,—leads to the conclusion that the Niagara Falls are 31,000 years old and the river of 32,000 years duration; also that the Huron drainage turned from the Ottawa river into Lake Erie less than 8,000 years ago. Lastly, if the rate of terrestrial deformation continues as it appears to have done, then in about 5,000 years the life of Niagara Falls will cease, by the turning of the waters into the Mississippi. These computations are confirmed by the rate and amount of differential elevation recorded in the deserted beaches. It is further roughly estimated that the lake epoch commenced 50,000 or 60,000 years ago, and there was open water long before the birth of Niagara in even the Ontario basin, and that under no circumstances could there have been any obstruction to the Ontario basin, if even then, later than the end of the Iroquois episode which has been found to have ended 14,000 years ago.

ART. LXIV.—*Resonance Analysis of Alternating Currents;* by M. I. PUPIN, Ph.D., Columbia College. Part II.

ADDITIONAL evidences proving the correctness of its indications referred to in the last paragraph will be found among the results of the following experiments.

IV.—*Location of the Origin of Upper Harmonics.*

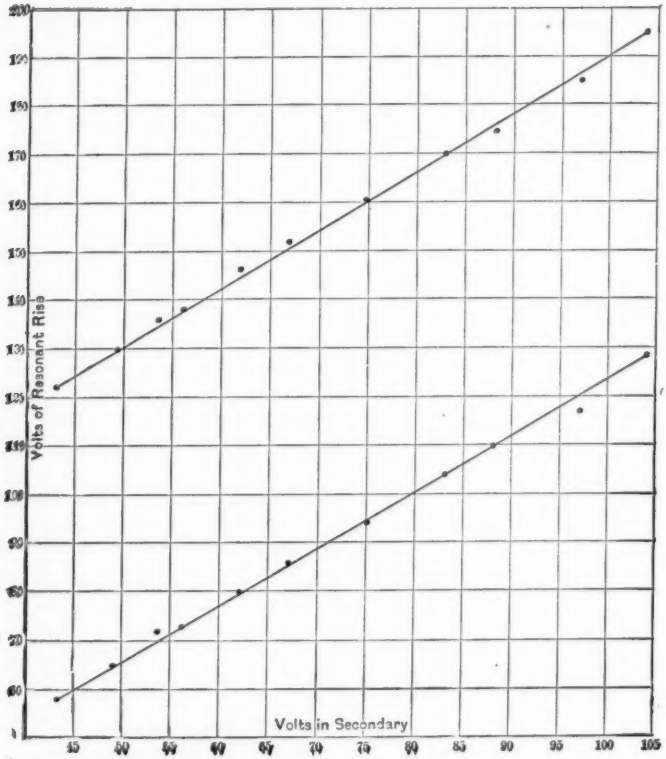
A. Experiments with alternator of smooth core armature.

1st Series.—The first set of experiments in this direction was performed with the 10 H. P. Fort Wayne 8 pole alternator with smooth core armature and the Stanley 5 K. W. transformer (closed magnetic circuit). The secondary circuit carried no load and a Cardew voltmeter indicated the secondary voltage. The current which excited the field of the alternator was gradually increased. The secondary voltage measured the strength of this excitation. The air core transformer with the resonator was inserted into the primary circuit as indicated in fig. 1^b. The resonant rise of potential, recorded by the multicellular voltmeter e', was carefully determined at every excitation for the fundemental frequency and for the first odd harmonic. Higher harmonics were present but very faint. The results are given in Table IV and plotted in fig. 5. The initial voltage in the resonant circuit was small, just perceptible in the multicellular voltmeter.

TABLE IV.

Secondary voltage.	Resonant rise in volts due to the fundamental.	Resonant rise in volts due to the first odd harmonic.
43	122	58
48	130	65
53·5	136	72
56	138	73
62	146	80·5
66·75	152	86
75	160	94
83	170	104
88	175	110
97	185	117
104	195	128·5

5.



The curves in fig. 5 were plotted from this table by taking the readings of the first column for the abscissæ and the corresponding readings of the second and third columns for ordinates. The upper curve corresponds to the fundamental and the lower curve to the harmonic. *The two curves are two straight lines parallel to each other*, which means *that the fundamental and the harmonic increase at the same rate from nearly one third excitation to full excitation of the alternator.* This result was not expected, but its correctness was verified beyond all reasonable doubt.

The same series of experiments was extended to lower excitations of the alternator, but, since I had no low reading alternating current voltmeter, the excitation was measured by measuring the exciting field current. This current was 10 amperes at full excitation and the series of experiments extended down to 1·5 amperes, hence to nearly one seventh of

the full excitation. To bring the readings of the resonant rises of potential within the scale of the multicellular voltmeter at these low excitations the number of turns in the air-core transformer was suitably increased. *Within all these limits of excitation both the fundamental and the harmonic increased at the same rate and proportionally to the magnetization of the transformer core.* This magnetization extended between about 600 and 4000 C.G.S. lines of force per square centimeter.

2d Series.—To determine whether the presence of the harmonic was due to the action of the transformer or to that of the alternator the transformer was disconnected from the alternator and two series of incandescent lamps, connected in parallel, were substituted in its place. Each series consisted of 13 twenty-four candle power lamps. The resonator with its air-core transformer remained in circuit as before. First one series of lamps was placed in circuit. The rise due to the fundamental was stronger than in the preceding experiments, but that due to the harmonic was exceedingly faint. When both series of lamps were thrown in the harmonic appeared a trifle stronger but still very weak. Hence the inference, that the harmonic was due almost exclusively to the action of the transformer.

It should be observed here that the alternator armature, though well laminated, runs fairly hot in a short time, hence it must be the seat of a decidedly strong hysteretic action. On the other hand the transformer does not heat nearly as much as the alternator armature and yet its action produces the harmonic. This certainly seems to speak strongly against the view that harmonics are due to hysteresis. Other evidences against this view will be given below.

3d Series.—A series of experiments with open magnetic circuit transformers of induction coil type in place of the lamps showed the harmonic much stronger than the lamps did, but considerably weaker than the experiments with the transformer with closed magnetic circuit. Accurate numerical comparisons between the two types of transformers in this respect was not attempted. It sufficed to establish that, *closed magnetic circuit transformers distort the primary current considerably more than transformers with open magnetic circuits under equal degrees of magnetization;* on the other hand, in the first case the distortion is confined almost entirely to the primary circuit when the secondary is closed by a non-self-inductive resistance, whereas in the second case it is felt in the secondary circuit also, though considerably less than in the primary.

The general conclusions of this group of experiments may be summed up as follows:

I. *A ferric self-inductance in circuit with an alternator which gives a simple harmonic electromotive force distorts the current by introducing higher odd harmonics, principally the harmonic of three times the frequency of the fundamental.*

II. *This harmonic* (and in all probability all other harmonics) *increases at the same rate as the fundamental when the excitation increases, the rate of increase being up to 4000 C. G. S. lines of force per sq. centim proportional to the intensity of magnetic induction.*

III. *When this ferric inductance is a transformer then the distortion appears in the induced secondary electromotive force, if the transformer has an open magnetic circuit, it does not appear there* (*to any extent worth considering*) *if the magnetic circuit is a closed one.*

IV. *A practically simple harmonic electromotive force is produced by alternators with smooth core armatures when symmetrically wound, even if the machine is worked at considerable degrees of magnetization of the armature core.*

B. *Experiments with alternator of slotted core armature type.*

The machine employed in these experiments was the 1 H. P. alternator mentioned above. It is a 16 pole machine with slotted armature core. It gives at full excitation and the speed at which it was usually run in these experiments about 1500 volts.* The transformer connected with it was of induction coil type with a cylindrical iron core made up of very carefully insulated fine iron wire. The same series of experiments were performed as under group (A). *The first series* in this group gave exactly the same results as the corresponding series in group (A). The excitation varied from one-seventh of the full to full excitation; the amplitude of the fundamental and the first odd harmonic† varied at the same rate during the whole interval, so that a parallel pair of straight lines like those in fig. 5 could be plotted in this case also. *The second series* resulted in the conclusion that *the harmonic was very strong and due*, in a very large measure, *to the action of the armature and not to that of the transformer* as in the other case, although the transformer, also, contributed a distinct but

* A more complete description of this machine and the transformer will be found in this Journal, June, 1893, p. 510, etc. Owing to an accident which somewhat impaired the insulation of the armature the machine was run last year at low excitation and hence low voltage although the speed was then considerably higher.

† The second odd harmonic, that is the harmonic whose frequency is five times that of the fundamental was there but weak.

comparatively small share to the strength of the harmonic. *The third series* showed that the harmonic appears in the secondary of an open magnetic circuit transformer although considerably weaker, but does not appear there to any appreciable extent when the magnetic circuit of the transformer is a closed one.

To the four conclusions given at the end of the series of experiments under group A the following additional conclusions may, therefore, be added:

V. *An alternator with slotted core armature produces a complex harmonic electromotive force in which the upper harmonic of three times the frequency of the fundamental is generally by far the strongest.*

VI. *The amplitudes of the fundamental and the harmonic increase at the same rate with the increase of excitation; this rate is within the limits of magnetization mentioned above proportional to the excitation, that is to say, proportional to the magnetization of the armature.*

VII. *A ferric inductance in circuit with a slotted iron core armature introduces no new harmonics. It strengthens those already existing in the electromotive force, that is odd harmonics, especially the first odd harmonic.*

The same conclusions will evidently hold true for alternators of ordinary types whose armature is made up of coils wound on iron cores which are bolted to a cylindrical iron drum common to all of them.

High degrees of magnetization of the transformer core produce a strong deformation of the primary current wave. With inductions of over 12000 C. G. S. lines of force per sq. cm. it is possible to make the amplitude of the 1st odd harmonic even greater than the amplitude of the fundamental. It is evident, therefore, that the parallelism of the lines in fig. 5 ceases as soon as the magnetization curve of the transformer core begins to approach the knee. Experiments relating to this point will be described in the near future. The experiments described in this paper were limited to conditions met with in the operation of commercial alternating current apparatus.

V. *Effect of the load upon the harmonics.*

It is a well known fact that the distortion of the primary current disappears gradually with the increase of the secondary load, that is when the external part of the secondary circuit is a non-self-inductive resistance. The question arises now, what becomes of the harmonics which produce the distortion of the

primary current when the secondary current increases. The following experiments seem to answer this question definitely:

The arrangement of circuits was that given in fig. 1[b]. The secondary circuit of the large 5 K. W. transformer contained an electrolyte resistance and the secondary current was measured by means of a Siemens electro-dynamo-meter. For every particular value of the secondary current the resonant rises of potential due to the harmonic and the fundamental were carefully determined by means of the multicellular voltmeter. Table V contains the observations relating to the harmonic of three times the frequency of the fundamental; Table VI relates to the fundamental (130 P. P. S.) The apparatus employed were the large alternator and the 5 K. W. transformer.

TABLE V.

Secondary current in amperes.	Resonant rise of the harmonic in volts.
0	65
3·6	65
4·8	66
6·9	68
8·5	70
11·5	76
15·7	85
20	97
28	120
40	162·5
56	202

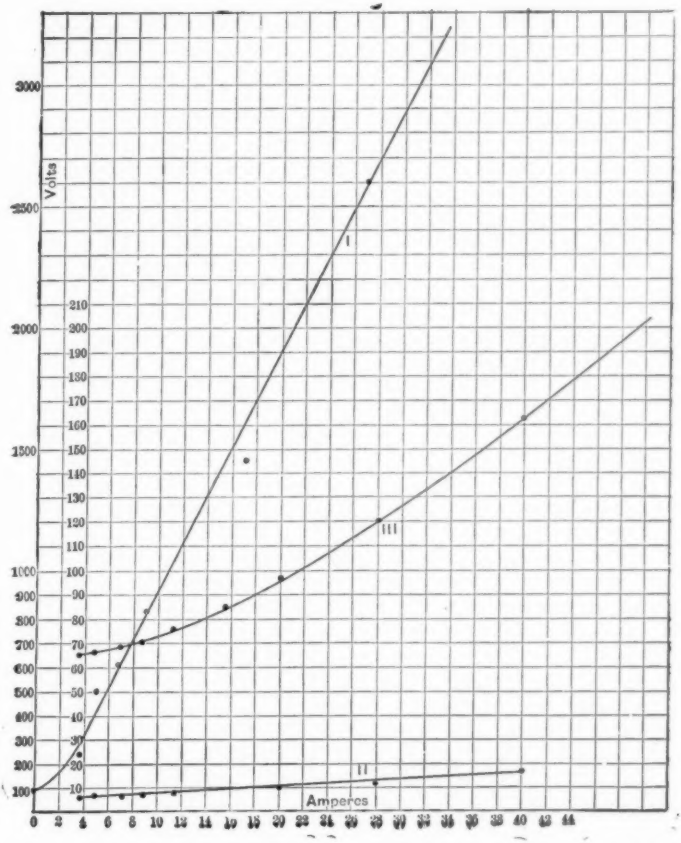
TABLE VI.

Secondary current in amperes.	Resonant rise of the fundamental in volts. (Observed.)	Auxiliary resistance in the resonator in ohms.	Resonant rise of the fundamental in volts. (Calculated.)
0	80	0	80
3·6	240	0	240
5·0	122	50	503
6·7	150	50	613
9·0	200	50	825
17·3	200	100	1,450
27·0	185	210	2,513
44·0	155	410	4,127
56·0	160	510	5,100

Table VI requires explanation. When the secondary current was over 3·6 amperes the resonant rise of the fundamental was too high for the voltmeter employed and also too risky for the condenser. An auxiliary resistance had to be introduced into the resonator to bring the resonant rise down to the limits

of the voltmeter. These auxiliary resistances are given in the third column. The readings that would have been obtained without these auxiliary resistances were then calculated, roughly, as follows: According to theory which was verified

6.



by experiments described in the beginning of this paper the resonant rise multiplied by the resistance of the resonator is within certain limits mentioned above independent of these resistances. The resistance of the resonator coils was 16 ohms. Hence, if, for instance, x denote the rise which would have been obtained without auxiliary resistance in the resonator when the secondary current was 5 ampères, then since with an

auxiliary resistance of 50 ohms the resonant rise was 122 volts we have with a rough approximation,

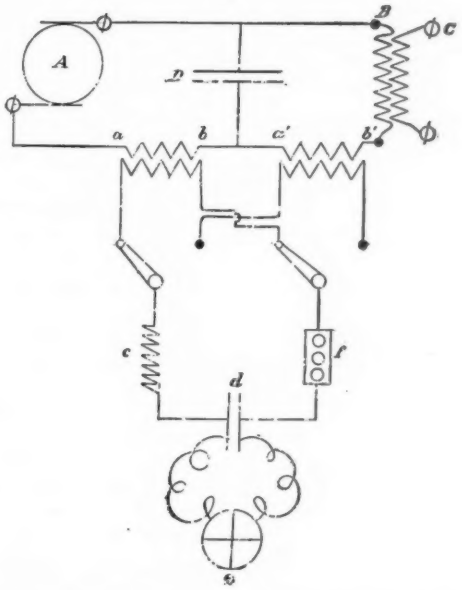
$$x = \frac{122 \times 66}{16} = 503 \text{ volts.}$$

In this manner the figures of the fourth column were obtained. They are only very rough approximations, but still they give a fair idea of the ratio of the fundamental to the upper harmonic at various loads. Curves I and II, fig. 6, were plotted from these data. The secondary ampères were taken for the abscissæ and the corresponding resonant rises in volts for the ordinates. Curve III represents Curve II plotted on a different scale for the volts of the resonant rise of potential. These are given in the right hand vertical column of the diagram. This curve gives a better picture of the gradual *apparent* increase of the harmonic. An inspection of I and II shows clearly how much more rapidly the fundamental increases than the harmonic. *In reality the increase is even more rapid;* for according to Table V it appears as if the strength of the harmonic increased with the secondary current, only much less rapidly than the fundamental. For instance, at open secondary the voltmeter indicated 65 volts for the resonant rise of the fundamental; and at 56 ampères in the secondary this rise was indicated by 202 volts. *But it must be noted that in the first case the voltmeter needle went from practically zero at no resonance, to 62 when resonance was reached; whereas in the second case it went from 135 volts at no resonance to 202 volts when resonance was reached, so that the real resonant rise was practically the same in both cases.* Similarly for all other loads in the secondary. It follows, therefore, that if the harmonic increased at all with the increase of the load this increase was much smaller than appears at first sight from the data of Table V. The more important conclusion, however, which follows from this experiment and which I wish to point out more particularly is that *the harmonic which manifests itself in the distortion of the primary current when there is no load in the secondary is present at all loads, if not stronger, then certainly with about the same strength. At full load this harmonic could not possibly be detected by Joubert's method of sliding contact; it is so exceedingly small in comparison to the fundamental.*

This persistence of harmonics at all loads even when completely hidden by the fundamental wave holds true also when their origin can be traced to the action of the armature of the generator as in the case of the machine with slotted iron core armature. *In all cases their strength depends upon the mean intensity of magnetization of the magnetic circuits to which they owe their origin and upon nothing else.*

Another somewhat more difficult but very instructive way of proving the persistence of the harmonics is represented in fig. 7. In circuit with the primary of the large machine and transformer described above are two equal air-core transformers, *a b* and *a′ b′*. By means of a double switch either one of the two can be made a part of the resonator circuit, *c d f*. A number of condensers, D, in series, are connected across primary circuit as indicated. The two air-core transformers, *a b* and *a′ b′*, will be equivalent when the resonator voltmeter *e* gives the same indications, no matter which one of the two transformers be connected to the resonator. This balanced arrangement having been obtained, the balance will be disturbed as soon as the condenser D is plugged in, and it will be

7.



disturbed in a great variety of ways, according to the capacity plugged in. But when the transformer B is of closed magnetic circuit type, then the resonator indications remain practically the same as long as the resonator is switched on the air-core transformer *a′ b′*, no matter what capacity is plugged in the condenser D. When the resonator is switched on the air-core transformer, *a b*, then its indications will be different for every particular capacity in D. In fact the circuit A, *a*, *b*,

D, A, can be treated as an entirely separate circuit from the circuit A, *a' b'*, B, A.

This statement needs practically no modification in order to cover that case also in which the self-inductance of the primary of B is diminished by putting a non-self-inductive load on the secondary. This utter disagreement between theory and experiment deserves a closer discussion, but since its connection with the subject of this paper is only an indirect one I prefer to reserve it for some other time. That which has a direct bearing upon the present discussion is the method which the above mentioned relation offers for observing the variation of the harmonics with the load without the disturbing inductive effect of the large primary current. It is this: Connect the air-core transformer *a b* (and with it the resonator) in series with the condenser. Add to this series an auxiliary coil *c* (no iron core). By the combination, thus obtained, bridge the primary circuit, so that in place of the simple condenser bridge D given in fig. 7 there will be a bridge consisting of condenser D, the air-core transformer *a b* and the auxiliary inertia coil *c*. The secondary C being open, tune the circuit consisting of the alternator armature, the primary conductors up to the bridge, and the bridge, to any one of the harmonics. The tuning is done by means of varying the capacity of the condenser and the self-inductance of the auxiliary inertia coil. Then close the secondary circuit by means of an electrolyte resistance and vary the secondary current. It will be found that the harmonic diminishes only slightly with the increase of the secondary load. As an example I give the following: The circuit just mentioned was tuned to the harmonic of five times the frequency of the fundamental, that is 650 p. p. s. At no load the resonator indicated a rise of 108 volts, at overload (56 ampères) the rise was 94 volts. But this drop was in all probability caused by armature reaction.

Whatever the ultimate meaning of the appearance and the persistence of the odd harmonics in an alternating current wave may be I am not quite prepared to state with any high degree of confidence. *One thing is certain and that is that they are at present at all loads with almost constant strength. Their presence is hidden by the fundamental wave at large loads, but when conditions favoring resonance with any one of them arise they will certainly come out and do all the mischief they can to the insulation.* The self-induction of a motor or that of a closed magnetic circuit transformer does not necessarily affect the conditions of their resonance. These conditions may depend in such circuits solely upon the self-induction of the alternator on the one hand and the self-induction and static capacity of the line on the other. According to the

experiments just described the resonant current is then confined entirely to the alternator and the line, the di-electric forming a part of its circuit. These observations will be modified in the case of transformers with open magnetic circuits and their equivalents, that is, closed magnetic circuits possessing considerable magnetic leakage, especially when the conditions of the line favor resonance with the fundamental frequency, this frequency being low; such magnetic circuits possess much less magnetic sluggishness and can influence considerably the conditions of resonance with a low frequency.

VI. *Distortion of the secondary current.*

It was pointed out that the superposition of harmonics upon the fundamental wave was confined to the primary circuit when the secondary is closed by a non-self-inductive resistance, that is, if the transformer is of closed magnetic circuit type. With an open magnetic circuit transformer the deviation of the primary current wave from the simple harmonic form, due to action of the generator or the transformer or both, is felt more or less in the secondary circuit also. If, however, the secondary is closed by a ferric self-inductance then odd harmonics will appear in this circuit also in both types of transformers. *In fact, the secondary circuit should now, as far as the harmonics are concerned, be considered as a separate circuit, in which the secondary coil of the transformer and the ferric inductance in the secondary circuit play the same part as the armature of the alternator and the transformer in the primary circuit.*

The series of experiments which related to the origin and growth of harmonics in the secondary circuit was similar to the one described above, by means of which the so-called distortion of the primary current was studied. The results were similar. The presence of harmonics is due to the action of the ferric inductance; their strength increases proportionally to the intensity of magnetization of the iron in the ferric inductance. They seem to be entirely independent of hysteresis, that is, if by hysteresis the process be understood by means of which most of the heat is generated in a very finely laminated, well insulated and well annealed iron core, when such a core is subjected to rapid reversals of magnetism. I shall describe briefly an experiment bearing upon this point. The secondary circuit of the five K. W. transformer was closed by an electrolyte resistance, and a short cylindrical coil having about 120 turns coarse copper wire. A short cylindrical core made up of very fine (No. 26 B. and S.), and well annealed iron wire could be inserted into this coil. The core was 40^{cm} high and 5^{cm} in diameter. The

wires were fairly well insulated from each other. A layer of fine copper wire surrounding this coil formed part of the resonator circuit. First, the secondary current was passed through the coil before the iron core was inserted. The resonator could detect no harmonic worth mentioning even when the current was increased almost to full load. But as soon as the iron core was introduced the odd harmonics appeared, especially the third harmonic; its strength increased proportionally to the current. Placing now another similar iron core on the top of the first and adjusting it in such a way that it allowed a small rocking motion the two cores could be set into violent vibration by the inductive attraction between them. This vibration manifested itself by a very loud note corresponding in pitch to the frequency of the alternator. The vibration could be diminished very much by pressing the top core against the lower core and against the table. The vibration produced no appreciable difference in the strength of the harmonic; if anything it seemed to make it stronger. Mechanical vibration produced by striking the cores produced no appreciable change in the harmonic. These experiments seem to me to render the theory which ascribes the origin of harmonics to the hysteretic action of iron completely untenable.

I do not think that the proper time has arrived yet for the formulation of a physical theory which will give a complete account of the peculiar behavior of iron, by means of which it superposes odd harmonics upon the wave of a simple harmonic current. The view which irresistibly suggests itself to my mind is simply this: Upper harmonics will be generated whenever more or less abrupt changes of the magnetic state in any part of the magnetic field through which an alternating current flows occur. A slotted core armature or an armature made up of coils with iron cores distributed over a drum common to all of them will introduce such changes. An alternating current induction motor, especially when it is not of a smooth core armature type, will also cause abrupt changes of magnetism and hence cause strong deviations of the feeding current from the simple harmonic form. But if this view be correct, then every complete cycle of magnetization to which iron is subjected when under the inductive action of a simple harmonic current must be accompanied by some abrupt changes in magnetism, and that, too, whether the mean magnetic intensity of the cycle be large or small. One thing seems certain and that is, that hysteresis, as commonly understood, will not account for these abrupt cyclic changes; for, if they really exist and are the cause of harmonics, they are certainly not affected by mechanical vibrations by which, as is well known, all hysteretic effects are influenced very much. But whatever the real

theory underlying these upper harmonics may be, the bare fact which the engineers have to face is: *There is no cure against harmonics as long as the circuits contain iron.* Hence, construct lines in such a way that conditions favoring resonance with the frequency of the fundamental or with one of its odd upper harmonics will seldom occur, and whenever they do occur the resonant rise of potential should not be capable of producing any damage. *Avoid slotted armatures and armatures with projecting pole pieces and keep the magnetization down as much as possible.*

VII. *Analysis of rotary magnetic fields.*

Before closing this paper I will describe briefly the application of the resonance method of analysis to the study of the intensity fluctuations of a rotary magnetic field. The investigation was carried out by two students of the Electrical Department of Columbia College, at my suggestion, and will be published in the near future. The method, briefly stated, is this: A suitable number of turns of wire are subjected to the induction of a rotary magnetic field. These turns form part of a resonator. Whatever fluctuations there be in intensity of the rotary field they will be periodic, their period bearing a perfectly definite relation to the periodicity of the current which produces the rotary field. For instance, in a three-phase combination of alternating currents the intensity of the rotary field will, according to theory, show six maxima and six minima during each complete revolution, the maxima differing from the minima by about 14 per cent. A circuit, subject to the inductive action of such a field should have a periodic electromotive force induced in it whose frequency will be either three or six times the frequency of the fundamental, according to the shape of the curve of fluctuations. Similarly in a rotary magnetic field produced by a two-phase combination of alternating currents. If such electromotive forces were induced the resonator would detect them, and from the resonant rise of potential the extent of the fluctuations producing these electromotive forces could be estimated.

No electromotive forces of this type were detected in either a triphase or a two phase combination. Hence the inference: *Rotary magnetic fields produced by reasonably well constructed machines are not accompanied by fluctuations in their intensity.*

Electrical Engineering Laboratory,
School of Mines, Columbia College, New York, May 10, 1894.

ART. LXV.—*Distribution and Probable Age of the Fossil Shells in the Drumlins of the Boston Basin;* by W. O. CROSBY and HETTY O. BALLARD.

So long ago as during the Revolutionary war, Gen. Benjamin Lincoln noted that in digging a well 90 feet deep in the fort on Telegraph Hill, in Hull, many shells were found, the shells extending from near the top of the ground to the bottom of the well.* Seventy-five years ago it was recorded that fragments of clam shells had been found 40 feet below the surface at Jamaica Plain, and at the depth of 107 feet in digging the well at Fort Strong, which was built in 1814 on Noddle's Island, now East Boston.†

But the first observer to note the occurrence of shells in the natural sections of the drift hills in the vicinity of Boston was Dr. William Stimpson, who published in 1851 a list of the fourteen species named below, which he found in the sea-cliff at Winthrop Great Head, then a part of Chelsea:‡ *Balanus crenatus*, *Chrysodomus decemcostatus*, *Tritia trivitatta*, *Urosalpinx cinerea*, *Mya arenaria*, *Ensatella americana*, *Mactra solidissima*, *Venus mercenaria*, *Cyclocardia borealis*, *Astarte undata*, *Astarte castanea*, *Mytilus edulis*, *Modiola modiolus*, *Ostrea virginiana*. About twenty-five years ago, in digging a well in Fort Warren on George's Island, shells were found 100 feet below the surface and about 40 feet below the sea level.§ In 1888 Mr. W. W. Dodge added, doubtfully, three species—*Lacuna neritoidea*, *Tapes fluctuosa*, and *Cardium islandicum*—to Stimpson's list from the Great Head section;‖ and noted the occurrence of shells in Grover's Cliff on the northeast shore of Winthrop, nearly one and a half miles north of Great Head.¶

Stimpson believed that the shells were contemporaneous with the enclosing drift, and regarded them as evidence of a marine submergence within the Pleistocene or Quaternary period. This view appears to have been generally accepted, or at least not to have been questioned, until 1886, when Lewis

* Geographical Gazetteer of the Towns in the Commonwealth of Massachusetts, 1785, p. 56. (Only a small part of this work was published.)

† Outlines of the Mineralogy and Geology of Boston and its vicinity, with a geological map. By J. Freeman Dana, M.D., and Samuel L. Dana, M.D., 1818, p. 96.

‡ Proc. Boston Soc. Nat. Hist., vol. iv, p. 9.

§ Reported by Prof. W. H. Niles in the Proc. Boston Soc. Nat. Hist., vol. xii, 1869, pp. 244 and 364. In commenting on this discovery Mr. T. T. Bouvé read a letter from a gentleman in Hull noting similar facts known to him in his own vicinity (p. 364).

‖ This Journal, III, vol. xxxvi, p. 56.

¶ Proc. Boston Soc. Nat. Hist., vol. xxiv, p. 129.

showed* that the similar but more impressive occurrences in Great Britain, where shells are found in the till to a maximum height of 1350 feet above the sea, do not require a submergence of the land or any change of level; but rather that the shells and fragments of shells found on the mountains of Wales, etc. had simply been plowed up by the ice-sheet during its passage across the bed of the Irish Sea and incorporated with the normal drift. The shells are thus to be regarded as preglacial inhabitants of the Irish Sea, and they owe their present positions entirely to the agency of the ice-sheet.

Three years later, Upham applied this theory to the explanation of the shells in the till of the Boston Basin.† He examined many of the till sections in and about Boston Harbor, and proved that the distribution of the shells is very restricted, and that in no direction are they found far beyond the present limits of the harbor, adding seven new localities and four new species to what were known before. His tabulated list shows for the most prolific of the new localities, Peddock's Island, five species, as against eighteen then known for Great Head, Winthrop. Upham also pointed out more clearly than had been done before for this region the usual conditions of the occurrence of the shells, viz: in more or less fragmental forms in the entirely undisturbed, unmodified and unoxidized till. The shells are to be found, as a rule, only in deep sections, simply because they have been gradually removed from the superficial, oxidized till through the solvent action of meteoric waters.

In this Journal for February, 1894, Mr. R. E. Dodge has added four species—*Lunatia groenlandica*, *Scapharca transversa*, *Buccinum undatum*, and *Ilyanassa obsoleta*—to those previously found at Great Head, bringing the list for that locality up to twenty-two species, or twenty-five species for the entire Boston Basin,‡ six species only being known from points outside of Winthrop, three of which are included in the Winthrop list. Mr. Dodge was, apparently, not aware that one of the present writers§ had previously published a list of eleven species found in the drumlins of the Nantasket peninsula, this list including three of those named by him as new for Great Head, viz: *Ilyanassa obsoleta*, *Buccinum undatum*, and *Scapharca transversa*, and one other new species, *Crucibulum striatum*.

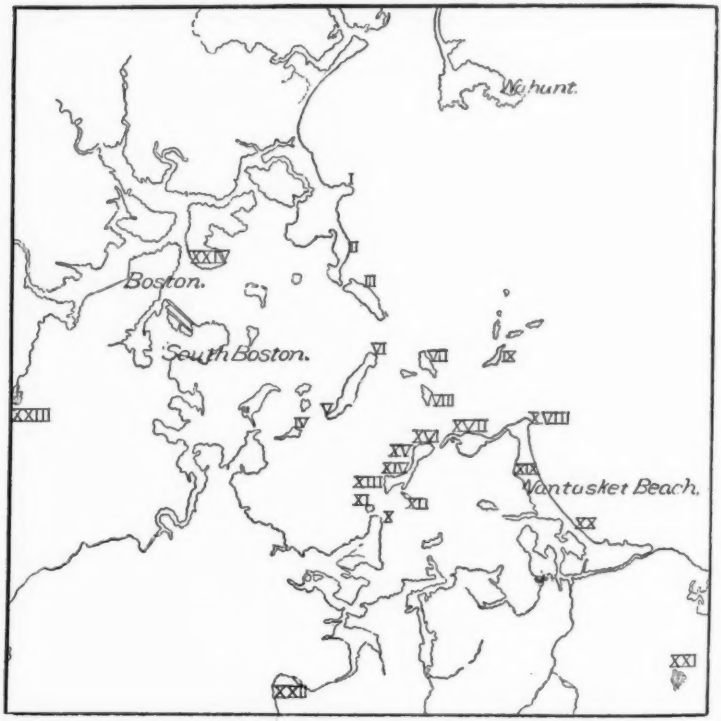
* Report of the British Association for Adv. of Sci., Birmingham, 1886, pp. 632–635; Am Naturalist, vol. xx, pp. 919–925, November, 1886; this Journal, III, vol. xxxii, pp. 433–438. December, 1886. Also. see American Geologist, vol. ii, pp. 371–379, December, 1888.

† Proc. Boston Soc. Nat Hist., vol. xxiv, pp. 127–141.

‡ Mr. Dodge has made these numbers 23 and 26, respectively, but this appears to be an error in addition.

§ Occasional Papers, Boston Soc. Nat. Hist., vol. iv, p. 142.

In connection with a systematic study of the geology of the Boston Basin, we have made a careful search for fossils in all the deep drift sections now accessible, more than doubling the number of localities and extending the list of species from twenty-six to forty-seven. Following is a list of the twenty-one new species which we have added to the drift fauna. *Cancer irroratus*, *Balanus balanoides*, *Fusus tornatus*, *Neptunea pygmæa*, *Sipho spitzbergensis*, *Buccinum cyaneum*, *Purpura lapillus*, *Anachis avara*, *Lunatia triseriata*, *Crepidula convexa*, *Crepidula plana*, *Crepidula fornicata*, *Zirfæa*



Map of Boston Harbor, showing the distribution of the fossiliferous drift sections.
Scale, 1 inch=4 miles.

I, Grover's Cliff; II, Winthrop Great Head; III, Deer Island; IV, Moon Island; V, West End of Long Island; VI, Long Island Head; VII, Lovell's Island; VIII, George's Island; IX, Great Brewster Island; X, Quincy Great Hill; XI, Nut Island; XII, Princess Head; XIII, XIV, XV, XVI, Peddock's Island; XVII, Telegraph Hill, Hull; XVIII, Point Allerton, Hull; XIX, Strawberry Hill, Hull; XX, Sagamore Head, Hull; XXI, well on James' Hill, Cohasset; XXII, well in Braintree; XXIII, well in Jamaica Plain; XXIV, well in East Boston.

crispata, *Siliqua squama* (?), *Mulinia lateralis*, *Saxicava norwegica* (?), *Cyprina islandica*, *Callista convexa*, *Anomia glabra*, *Pecten magellanicus*, *Astrangia danæ*.

In this Journal for March, 1894, Mr. Upham calls attention to the previously unpublished observations of Mr. Warren W. Herman, a zealous collector, who had found at Great Head the four new species subsequently published by Mr. Dodge, and one other—*Crepidula plana*. Mr. Herman, who has kindly placed his results at our disposal, has examined carefully only three sections—Great Head, Grover's Cliff and Telegraph Hill. He has found in all thirty-five species, eight of which have not been found by any other observers; viz: *Neptunea ventricosa*, *Sipho stimpsoni*, *Astyris lunata*, *Bela* (sp.), *Utriculus canaliculatus*, *Petricola pholadiformis*, *Macoma fragilis*, and *Argina pexata*. This brings the number of the drift species up to fifty-five.

The accompanying map shows the distribution of all the known fossiliferous sections, including the wells noted by early writers in Jamaica Plain, East Boston, and on George's Island, and two other wells to which our attention has been called, one in Braintree and the other in Cohasset. The map is intended especially to show the relations of the fossiliferous sections to the outlines of Boston Harbor; and it is apparent at a glance that the facts support the views of Lewis and Upham. If the shells are preglacial inhabitants of the Boston Basin which were scraped up by the ice-sheet and incorporated with the normal drift, they ought to be found, as they are, chiefly in the central and southern portions of the basin, and overlapping its southern but not its northern margin. The non-occurrence of shells in the numerous drumlin sections along the southern shore of the harbor is readily explained by the fact that the sections are all too shallow. In fact, it may be said that fossil shells are found at every point where recent erosion has cut through the buff till into the unoxidized or blue till, say to a depth of thirty feet or more. That the shells do actually exist in these seemingly barren drumlins, and others still farther south, is proved by the wells just referred to. The facts are as follows: Fragments of the round clam (*Venus mercenaria*) were found by Mr. Titus Burbank some years ago in digging a well near the summit of James Hill (a typical drumlin), northeast of Scituate Pond in Cohasset. The well is 45 feet deep; and the shells were observed only near the bottom.* Seven years ago Mr. Charles H. Custance of Braintree dug a well at the house of Ibrahim Morrison on a flat irregular drumlin between Braintree and East Braintree; total depth 49 feet—29 feet in "gravel and

* Occasional Papers, Boston Soc. Nat. Hist., vol. iv, p. 143.

boulders" and 20 feet in "blue clay" (blue till). In the blue clay he found a shell. Similar facts in many other wells along the South Shore have, doubtless, escaped intelligent observation and record.

The collections made by Mr. Herman and ourselves show that several localities, notably Grover's Cliff and the east and west ends of Peddock's Island, rival Great Head in the abundance and variety of the fossils. The nine most prolific localities are embraced in the accompanying table. The remaining localities have afforded the species indicated below: West end of Long Island, 33, 38, 43, 55; Long Island Head, 2, 38, 43, 47, 55; Lovell's Island and Nut Island, 38, 43, 55; George's Island, 11, 19, 38, 43, 55; Quincy Great Hill, 33, 38, 43, 44, 55; Princess Head, 33, 38, 55; Peddock's Island, 2d drumlin, 33, 38, 43, 53, 55; Peddock's Island, 3d drumlin, 38, 55; Strawberry Hill, 38, 43, 45, 47, 55.

Previous writers, including Upham and Dodge, have cited the occurrence of similar fossils in the drift, either unmodified or modified, at other points along this Coast from Brooklyn, N. Y., to the mouth of the Saguenay, and have noted that not a single certainly extinct species has been found; and it remains now to add that our studies in the Boston Basin have not changed this important generalization. Upham has also considered the climatic changes indicated by the general facies of our drift fauna. Southern forms prevail, including the round clam (*Venus mercenaria*) which is enormously more abundant than all the other forms taken together, although now of rare occurrence north of Cape Cod. A few forms, however, have a northward range far beyond this latitude; and, as Upham states, the intermingling of characteristic southern and northern forms in this assemblage of fossils from the till seems to be readily accounted for by the gradual refrigeration of the climate which culminated in the formation of the ice-sheet. The distinctly postglacial fossils dredged in the vicinity of Boston, of which Upham has reported fifty-one species,* are also mainly southern forms. The evidence thus appears to be fairly conclusive that in preglacial and again in immediately postglacial times the climate in this latitude was milder than at present.

The solution of the shells by meteoric waters is plainly indicated by the facts that they are generally wanting in the superficial, oxidized zone, and that such as are found in this zone are commonly more fragile and have an etched or half-dissolved aspect. Where the shells have wholly disappeared, their former presence may in some cases be safely inferred from the lumps and concretionary masses of till which are found chiefly in the

* Proc. Boston Soc. Nat. Hist., vol. xxv, pp. 305–316.

LIST OF SPECIES IN THE TILL OF THE BOSTON BASIN.

SPECIES.	Great Head.	Grover's Cliff.	E. end Peddock's Id.	W. end Peddock's Id.	Deer Island.	Moon Island.	Telegraph Hill.	Point Allerton.	Great Brewster Id.
1. *Cancer irroratus*, Say			×	×					
2. *Balanus balanoides*, Stimpson	×	×	×	×	×	×	×		
3. *Balanus crenatus*, Bruguiere	×		×	×				×?	
4. *Bela* (sp.)	×								
5. *Chrysodomus decemcostatus*, Say	×			×					×
6. *Fusus tornatus*, Gould		×	×		×	×			×
7. *Sipho stimpsoni*, Morch	×						×?		
8. *Sipho spitzbergensis*, Reeve	×		×	×	×				
9. *Neptunea ventricosa*, Gray	×						×		
10. *Neptunea pygmæa*, Gould		×			×		×		
11. *Buccinum undatum*, Linné	×	×			×			×	
12. *Buccinum cyaneum*, Bruguiere			×						
13. *Tritia trivittata*, Say	×	×	×	×		×	×	×	
14. *Ilyanassa obsoleta*, Say	×	×					×		
15. *Urosalpinx cinerea*, Say	×	×		×		×			
16. *Purpura lapillus*, Linné	×	×	×	×	×				
17. *Anachis avara*, Say	×		×				×		
18. *Astyris lunata*, Say		×							
19. *Lunatia heros*, Say	×	×	×	×	×		×		
20. *Lunatia triseriata*, Say			×	×	×				
21. *Lunatia groenlandica*, Moller	×								
22. *Lacuna neritoidea*, Gould (?)	×								
23. *Crepidula fornicata*, Linné	×	×	×	×	×	×			
24. *Crepidula plana*, Say		×					×		
25. *Crepidula convexa*, Say				×					
26. *Crucibulum striatum*, Say		×	×	×			×		
27. *Utriculus canaliculatus*, Say		×							
28. *Zirfæa crispata*, Linné		×							
29. *Ensatella americana*, Gould	×		×	×	×	×		×	
30. *Siliqua squama*, Blainville (?)			×						
31. *Saxicava arctica*, Linné			×						
32. *Saxicava norvegica*, Spengel (?)	×								
33. *Mya arenaria*, Linné	×	×	×	×	×	×	×		×
34. *Mactra solidissima*, Chemnitz	×	×	×		×				
35. *Mulinia lateralis*, Say				×		×			
36. *Macoma fragilis*, O. Fabr		×							
37. *Petricola pholadiformis*, Lamarck		×							
38. *Venus mercenaria*, Linné	×	×	×	×	×	×	×	×	×
39. *Callista convexa*, Say		×	×	×	×		×		
40. *Tapes fluctuosa*, Gould (?)	×								
41. *Cyprina islandica*, Linné		×							
42. *Cardium islandicum*, Linné (?)	×								
43. *Cyclocardia borealis*, Conrad	×	×	×	×	×	×	×	×	×
44. *Astarte castanea*, Say	×	×	×	×			×		
45. *Astarte undata*, Gould	×	×	×	×	×	×	×	×	×
46. *Argina pexata*, Say		×					×		
47. *Scapharca transversa*, Say	×	×	×	×	×	×	×	×	×
48. *Mytilus edulis*, Linné	×	×?	×	×	×	×			
49. *Modiola modiolus*, Linné	×	×			×		×		
50. *Pecten magellanicus*, Conrad			×	×		×			
51. *Pecten islandicus*, Müller			×						
52. *Anomia glabra*, Verrill				×					
53. *Ostrea virginiana*, Lister	×	×		×	×	×			
54. *Astrangia danæ*, Agassiz		×	×						
55. *Cliona sulphurea*, Desor	×	×	×	×	×	×	×	×	×
	32	32	29	27	21	16	19	9	8

oxidized zone and are due to the very local cementation of the till by carbonate of lime, the most probable source of this cement being fossil shells which have vanished in this transformation. These masses of recent conglomerate or pebbly claystones range from a small fraction of an inch to several inches in diameter; are usually distinctly rounded in outline; and may occur loose in the till or attached to larger stones and bowlders. Although observed in several sections, they are especially noticeable in the buff till of Telegraph Hill; and one example from this section shows where broken the impression of a shell fragment, probably *Scapharca transversa*, with a minute portion of the original shell still remaining.

In part to the interstitial deposition of carbonate of lime from dissolved shells, but chiefly to the peroxidation of the iron oxide in the till, is due the setting or imperfect lithifaction of the buff till which causes the upper portions of the cliffs to present, usually, very precipitous or even vertical and overhanging profiles. That the buff till and the blue till are really contrasted in this respect is apparent from the fact that, no matter how high or how fresh the sea-cliff may be, the talus starts, as a rule, from near the junction of the two kinds of till, and the blue till can be seen *in situ* only where the slope is gullied.

The segregations of carbonate of lime are also found on the shells themselves, below the zone of most perfect oxidation of the till; the localities where this relation has been specially noted being Moon Island, the east and west ends of Peddock's Island, Deer Island, Point Allerton and Strawberry Hill. They occur almost exclusively on the larger and more massive shells, such as *Venus* and *Cyclocardia*; and are attached, as a rule, to the inner surfaces or the less salient portions of the shells, often filling the recesses of the hinge and the perforations made by the boring sponge—*Cliona sulphurea*. Occasionally, however, the shell fragments are almost entirely enveloped, forming the nuclei of concretions. In some cases, the segregations attached to the shells are protuberant and present the rounded outlines of normal concretions; but more commonly they have a worn or fragmentary character, as if they had suffered abrasion subsequent to segregation. These same shells frequently show glacial striæ; but in no instance, so far as we have observed, do the striæ cross the cemented material, although, on account of the rough and gritty character of the latter, one might well hesitate to speak positively on this point, but for the fact that prominent scratches are in some cases partly filled and covered by this natural concrete. This is an important point, since, in connection with the concretionary form of the segregations, it affords a conclusive

answer to the view, which might otherwise appear tenable, that we have in these segregations remnants of a preglacial lithified matrix of the shells. In fact, the form and mode of occurrence are, in many cases, strongly suggestive of such an explanation; and it is noteworthy that, although this adherent material is always of the same general nature and composition as the enclosing normal drift, it is also often much darker colored, varying from the usual gray tint of the till through dark brown to nearly black. Furthermore, the color is, in the thicker segregations, often noticeably darker in the portions lying nearest or in close contact with the shells. The blackness largely disappears on calcination, indicating that it is due to carbonaceous matter, the source of which, it appears probable, may be in the shell itself. This is one fact pointing to the conclusion that the shells, which are now white, opaque, more or less chalky, and as truly fossilized as many Tertiary shells, were recent in the fullest sense of the word at the time they were incorporated with the drift through the action of the ice-sheet; and it is in harmony with the fact that as yet no extinct species have been found in the drift.

Although the lithified matrix adhering to a small proportion of the drift shells must, in view of the foregoing observations, be regarded as of postglacial origin; and the shells themselves are probably immediately preglacial inhabitants of Boston Harbor; one of the sections has afforded shells in an apparently preglacial matrix. While searching for shells on the west end of Peddock's Island, we found a rounded and distinctly glaciated fragment of a highly fossiliferous rock. It is a gray, seemingly unstratified, argillaceous and distinctly calcareous mass, $6\frac{1}{2}''$ long and $2''$ in greatest diameter, enclosing grains and more or less angular pebbles up to an inch in length of slate and other rocks, such as are common in the local drift. In fact, it looks exceedingly like a lithified portion of the drift, except that it is literally crowded with comminuted shells—the shell fragments ranging in size from mere specks to nearly an inch in diameter. When first found, the specimen was completely imbedded in the solid and entirely undisturbed gray till, one end projecting slightly from the side of a rain-washed gully about 15 feet above the beach and 25 feet below the top of the cliff. In digging it out, it was broken in two, and the aspect of the section is similar to that of the surface. That it is a true glacial erratic and reached the position where it was found through the agency of the ice-sheet we can not doubt. On a later visit to the section in company with Mr. T. A. Watson, he found another fragment of nearly the same size and shape and of very similar character save that the enclosed pebbles are larger and the shell fragments fewer.

Both specimens are distinctly glaciated, showing longitudinal scratches over almost their entire surfaces.

Concerning the origin and history of these specimens two views are suggested: (1) They are fragments of consolidated till, the product of an earlier ice-sheet, which was cemented by the segregation of carbonate of lime, perhaps locally where the enclosed shells were most abundant, during an interglacial period. (2) They represent a wholly preglacial and probably late Tertiary deposit, an uneroded remnant of which may even now underlie the water and drift deposits of Boston Harbor. This view is not, *a priori*, improbable, when we consider that Cretaceous and Tertiary strata fringe the southern coast of New England, appearing again in Marshfield, Mass., only twenty-five miles from Boston, and undoubtedly underlying a part, at least, of Massachusetts Bay, as indicated by the fragments of rock carrying characteristic Eocene fossils found by Upham in the drift of Cape Cod and described by the senior writer.* The Peddock's Island fragments include both Gasteropods and Lamellibranchs; but owing to the fragmentary character of the shells and the firmness of the matrix we have been unable to satisfactorily identify any of the species. We feel no hesitation, however, in saying that the general aspect of the shell fragments is strikingly similar to those found in the till and that they quite certainly embrace *Venus*, *Cyclocardia*, *Scapharca*, *Natica* and other species of the till. But the chief facts telling against the Tertiary age of these specimens are the comminution of the shells and the similarity of the calcareo-argillaceous matrix to the till, and especially to the cemented or concretionary masses of till. In view of all these considerations, we believe that these fossiliferous erratics, which agree, in color, with the gray rather than the buff till, should be correlated with the cemented portions of the till previously described. Among the various forms which the cemented till assumes, the most important distinction is between the globular, distinctly concretionary and uneroded forms and the worn and glaciated forms, the two specimens from the west end of Peddock's Island belonging to the second class. The uneroded globular forms are clearly of postglacial origin and may be regarded as still forming; but that the eroded forms, including the glaciated masses form Peddock's Island, are not truly preglacial is indicated, as already noted, by the comminution of the shells and the decidedly till-like character of the matrix. The only alternative, therefore, is to regard them as, in some sense, interglacial. When the ice-sheet first invaded this area, the shells on the bottom of Boston Harbor were reduced to fragments and became a part of the

* Proc. Boston Soc. Nat. Hist., vol. xx, pp. 136–140.

ground moraine or till. During a recession of the ice-sheet, the till was locally cemented or lithified by carbonate of lime derived from the shells through the solvent action of meteoric waters, the still undissolved shells thus becoming, in some cases, completely enclosed in a firm matrix. During the second advance of the ice-sheet the shells suffered further comminution, and the cemented or lithified portions of the till were more or less broken up and abraded or glaciated. The arenaceous character of the till must favor the solution and segregation of the carbonate of lime of the shells; and it does not appear probable that the very limited amount of lithified till antedating the close of the ice age of which we have evidence required for its formation a prolonged recession of the ice-sheet, or a period amounting to a true interglacial epoch. Our studies may be regarded as lending some support to the duality of the ice age; but it does not appear that during the vigorous discussion of this question now in progress any agreement has been reached as to how extensive or prolonged the recession of the ice-sheet must be to constitute an interglacial epoch in any given latitude. Important and repeated recessions of the ice-sheet are conceded by all glacialists, and the glaciation must have been intermittent in lower latitudes while continuous in higher latitudes. Thus the ice-cap which now covers a large part of Greenland is probably a remnant of the great sheet whose southern margin was a few thousands of years ago in the vicinity of New York and Cincinnati; and the age in which we live may eventually prove to be interglacial. It does not appear to us, however, that the facts presented in this paper indicate more than a brief or temporary recession of the ice-sheet from Boston Harbor; and certainly we have no evidence that preglacial conditions were reëstablished here or that any of the shells now found in the till date from an interglacial period.

A nearly complete series of the drift shells, representing all the known sections except the wells, and including the glaciated rock fragments from the west end of Peddock's Island, has been added to the collection illustrating the geology of the Boston Basin in the Museum of the Boston Society of Natural History. Mr. W. H. Dall of the U. S. Geological Survey, and Professor A. E. Verrill, of New Haven, have kindly identified some of the more doubtful species; but we feel that the drift fauna of the Boston Basin is still very incomplete, and especially that we have missed several species on account of the hopelessly fragmentary and abraded character of the material. In the collection of the shells we have received important assistance from Mr. T. A. Watson, and from Mr. H. D. Card, Mr. G. W. Stose, Miss Elvira Wood,

and Miss E. F. Fisher, students in the Geological Department of the Massachusetts Institute of Technology. We also take pleasure in acknowledging our great obligation to Mr. W. W. Herman for freely placing his extensive collection at our disposal. To his zeal as a collector we owe not only a goodly number of the new species recorded in this paper; but many other species in his collection are new for the localities in which he found them.

Art. LXVI.—*An Improved Form of Interrupter for Large Induction Coils;* by F. L. O. Wadsworth.

Every one who has had occasion to use a large induction coil knows the difficulty of keeping the contact breaker in good working order. Of the two forms of interrupter in common use, i. e., the spring contact form and the well known Foucault form, the latter is best suited for large coils, because the "break" may be made to take place under water or alcohol and the rapid oxidation of the contact surfaces is thereby much reduced. Even under the best conditions, however, it is difficult to secure uniformity of working for any length of time, and this, together with the necessity for frequent cleaning of the parts and renewal of the alcohol and mercury, renders the apparatus anything but satisfactory, when continued use with heavy currents is desired.

In the last number of this Journal Mr. St. John* describes a form of mercury contact interrupter similar to the ordinary Foucault form, except that the plungers are positively driven by means of cranks geared to a small electric motor, instead of by the more uncertain action of an electro magnet. This undoubtedly will give more positive and uniform results than are obtained either with the Foucault form or the ordinary spring contact form, but it seems to me to be considerably more complicated than need be for the purpose.

I am convinced from my own experience that mercury contacts are unsatisfactory if the best results are to be obtained with large induction coils. The electromotive force induced in the secondary circuit depends on the sharpness of the break in the primary, and this is lengthened considerably by the oscillation of the mercury surface and the formation, (on account of the low boiling point of the liquid), when the break occurs, of a considerable amount of conducting vapor.

* Wave Lengths of Electricity on Iron Wires. This Journal, vol. xlviii, p. 316, October, 1894.

For these last reasons, and also on account of the rapid oxidation of the surface, even when covered with alcohol, such contacts are entirely unsuitable when exact *equality* of the successive discharge intervals is of importance. Another objection to this form of interrupter, which becomes a serious one when work requiring concentrated attention on the part of the observer is under way, is the noisiness of its operation.

About four years ago I designed a form of interrupter for Prof. Michelson, which has been used ever since for the large induction coil employed to excite the Geissler tubes containing the vapor of the substance whose radiations are to be examined by means of the wave comparer.* The conditions which the interrupter is here required to fulfill are unusually severe. In the first place the action should be as noiseless as possible, in order to avoid distracting the attention of the observer. It must be constructed so that it will run constantly, often for some hours, without any attention or readjustment, even when the current in the primary is varied from zero to its maximum value (15 to 20 amperes), and finally in order to secure a perfectly steady source of light, the successive discharges should be as regular as possible, both as regards intensity and duration. For certain portions of the work it was also essential that the spark interval should be very uniform and considerably less than is usually obtained with a spring interrupter whose amplitude of swing is sufficient to enable it to be used with currents of any magnitude. It was also desirable that the number of breaks per second might be varied within considerable limits without interfering with the action of the interrupter, and that the observer might be able to readily start or stop the latter without leaving his seat.

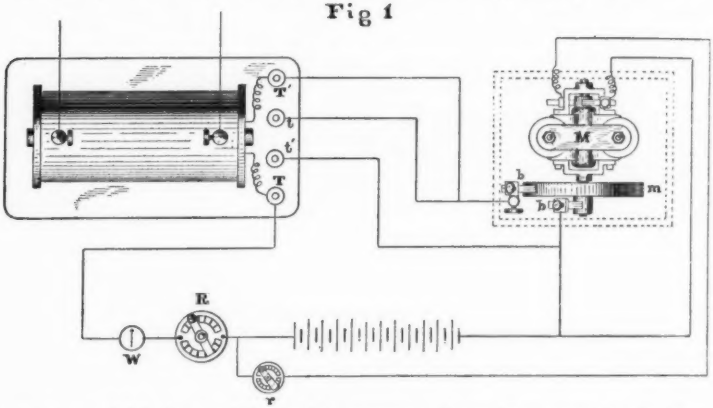
As all of these requirements have been satisfactorily met in the interrupter above referred to, and as it is, moreover, of very simple and inexpensive construction, it was thought that a brief description of it might be of interest to the spectroscopists and others who have had to use large coils for similar purposes.

It consists simply of a brass wheel about 6″ in diameter, with two insulating and two contact segments symmetrically placed in its circumference, and mounted directly on the shaft of a small electric motor making about 1200 revolutions per minute. Two copper brushes are arranged to bear, one on the hub of the wheel, the other on its circumference. A plan view of the arrangement, showing also the electric connections with the coil, is shown in fig. 1, where M is the motor (for an interrupter of this size a $\frac{1}{16}$ to $\frac{1}{12}$ H. P. motor is quite sufficient),

*See paper, Application of Interference Methods to Spectroscopic Measurements. II. A. A. Michelson. Phil. Magazine, vol. xxxiv, p. 280, Sept., 1892.

m, the revolving wheel; *bb*, the two contact brushes; TT, the terminals of the primary coil; *tt*, the terminals of the condenser; R, a rheostat for controlling the strength of the primary current; and *r*, one for controlling the speed of the

Fig 1

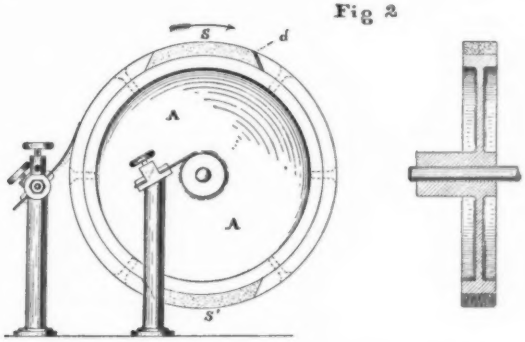


motor, which is supplied with current from the same batteries that feed the primary circuit. The current through the primary is broken each time one of the insulating segments on the circumference of the wheel passes under the contact brush *b*; the principle of its operation is therefore the same as that of the old toothed wheel interrupter. No novelty, therefore, can be claimed for it, except as regards the method of construction of the rotating wheel, but upon this depends almost entirely its successful operation, under the severe conditions of usage. In order that the action may be quiet, smooth and regular, it is of course necessary that the surfaces upon which the contact brushes slide, particularly the outer one, should be continuous, as regards outline; (i. e., not broken into teeth, as in the toothed wheel interrupter), and that they should be true at first, and remain so. The principal difficulty which had to be overcome was that of a rapid burning away of the material of which the insulating segments were made. It is unnecessary to record here in detail the various methods and materials which were at first employed in the attempt to secure a construction which would satisfactorily resist, without injury to itself, the heavy sparks of the "break." Hard rubber, vulcanite, vulcanized fibre, and even mica in its ordinary form rapidly burned or wore away. Finally cut slate segments were tried and have proved completely successful.*

*Porcelain segments would, perhaps, be even better, but the expense of making them (on account of the expense of making the necessary moulds, etc.) prohibited their use. The slate is a very satisfactory substitute and as it is easily worked the cost is comparatively trifling

To facilitate putting these segments in place and replacing them if accidentally broken, the construction shown in fig. 2 was adopted.

Fig 2



The hub, web, and flanged felloe of the brass wheel is cast in one piece and turned up true all over, so as to be perfectly balanced, even at high speeds. The insulating segments, ss', each about 50° in length, are cut so as to fit the curve of the outer face and are beveled off at each end as shown. They are held in place by two brass or copper segments of the same thickness and each 130° long,* which are screwed down to the face of the wheel A A. A piece of sheet platinum, d, about $\frac{1}{2}^{mm}$ thick (giving a beveled edge about 1^{mm} wide) is placed between the slate and the brass at the side on which the "break" occurs.

When the surface is first built up in this manner, and afterwards, whenever a new segment is put in place (which is necessary only in case of an accident), the wheel is placed in the lathe and the outer surface ground perfectly true with a small revolving emery wheel or block of stick emery held in the tool post.

With a wheel of the construction just described, the wear, even with the heaviest currents, is inappreciable, on either the brass or the slate segments, it being confined almost entirely to the outer brush. By making this of spring copper and mounting it as shown in fig. 2, at a small angle to the surface, so that it springs into contact with the latter as it burns away, no attention is required until the brush is used up, when it is but the work of a moment to replace it by a new one; a

*The object of this relatively greater length of contact interval is to allow time, even at the highest speeds, for the current to rise to its full value in the primary circuit before the latter is broken.

stock of them being kept constantly on hand. With a mean* current (as indicated by a direct reading Weston ammeter (W, fig. 1) placed in the primary circuit) of 5 to 6 amperes, a brush usually lasts four or five or sometimes ten hours without being replaced. No other attention is required except to oil the bearings of the motor occasionally.

The only noise is that caused by the whirr of the revolving parts and the snap of the spark, and this is almost completely deadened by supporting the motor on rubber blocks and enclosing the whole arrangement in a small wooden box (indicated by the dotted lines in fig. 1).

The circumferential speed is so high, nearly two thousand feet per sec.. that the break is extremely rapid and sharp. In the first instrument constructed the axis was vertical and the wheel was made to revolve under alcohol, but a short trial showed that this precaution was unnecessary.

If very heavy currents (15 or 20 amperes or higher) were continually used it would probably be found advantageous to place the contact-breaking brush between the poles of a powerful electromagnet (excited by the motor circuit). This would blow out the arc formed on breaking the circuit and thus greatly diminish the rate of burning away of the brush (see fig. 3). For ordinary work however neither this nor the use of a condenser is necessary although I have shown the latter connected to the interrupter in fig. 1.

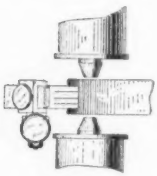


Fig 3

An alternating current dynamo properly wound is in many respects the most desirable means of exciting large coils, but on account of the expense of the dynamo itself and the cost of running it it is not often available. Even when it is there is one respect in which the action is inferior to that of an interrupter, viz: in the rapidity of the fall of electromotive force in the primary circuit. In this respect as well as in that of simplicity and cheapness the rotating wheel interrupter is superior to both the dynamo, and to all other forms of interrupters, and I do not think that any one who once gives it a fair trial will ever again use either a spring or mercury "break," for any but the very lightest work.

Addendum.—When this form of interrupter was first used it was noted that the spectrum of the spark at the "break" was very brilliant and pure and the possibility of using this spark as a source of radiation instead of an electric arc, suggested itself although not in any very definite form. This

*The maximum strength of current at the moment of breaking the circuit is, with the speed usually adopted, about twice the mean current as indicated above.

method has recently been developed by Prof. Michelson who in order to obtain spectra of difficultly volatile metals in vacuo, adopts the ingenious expedient of rotating the interrupter wheel in a Torricellian vacuum by means of a long shaft passing up through the mercury column.* A somewhat similar method has also been quite independently used for obtaining spectra of different metals in air by Messrs. Crew & Tatnall.†

It would seem to be a particularly promising one for the investigation of the infra red lines of the metals and alkali earths.

University of Chicago, October, 1894.

Art. LXVII.—*Post-Glacial Faults at St. John, N. B.*; By G. F. Matthew, D.Sc., F.R.S.C. (With Plate XI.)

Nowhere, so far as the writer is aware, has there been put on record any account of disturbances in post-glacial times, of the rocks along the lines of faulting, in this North-eastern part of America. There are numerous places in all parts of this region where the removal of drift deposits allows of the inspection of the glaciated surfaces of the rocks, and had such faults been common it would seem highly probable that their presence would long ere this have been noticed. This thought induces the writer to give a brief sketch of the numerous small displacements, produced since the glacial period that have been observed in the rocks in and near St. John, N. B., Canada.

Numerous proofs of post-glacial disturbances of the earth's crust are visible in the slate rocks which form a large part of the rocky foundation on which St. John is built. These are true *post-glacial faults*. They are well shown along the hillside south of "The Valley" in that city. This valley is an east to west depression in the northern section of the thickly inhabited part of the town.

The rocks along the southern slope of this valley consist of the fine, dark-colored shales or slates of the Bretonian or Upper Division of the St. John Group; which by their fine grain and uniform texture, are well adapted to preserve the sharp grooves and striæ impressed upon them in glacial times, by the moving ice.

The faults visible along this hillside belong chiefly to a system having approximately a N.E. to S.W. course, and a hade of

* Univ. of Chicago, 1893–4. Results not yet published.
† Phil. Magazine, vol. xxxviii, p. 379, October, 1894.

from 60° to 80° to the S.E. But these faults are traversed by diagonal ones, some with a course approximately N. to S. and others E. to W. The principal movement of faulting in post-glacial times has been along the fault planes that have a N.E. to S.W. course.

The place where these faults were first observed was on the side of City Road, north of the City Hospital. Here a glaciated surface of slate about twelve feet wide has been exposed by the removal of the surface soil. There are nine faults visible here having a course nearly parallel to that of the street and a hade to the S.E. They vary in downthrow from one quarter of an inch to four inches, the downthrow being in all cases on the *north side.*

Beside these faults of the northeast and southwest system, two faults diagonal to these were seen, these have a course approximately N.E. to S.W. and the downthrow in both cases, though small, is on the *north side.*

On the steep hillside east of the end of Charles Street, numerous small faults of the N. E.–S.W. system were seen. In all these the downthrows were on the *north side.* Here the diagonal faults are of more importance as regards the downthrow that at the exposure on City Road; the hade of these faults is also less, being about 50°; the course of these is different from that of the diagonal faults at City Road being approximately E.–W. The downthrows here are on the *north side* of the diagonal faults and on the *north side* of the faults that have (approximately) a northeast to southwest course.

The best display of the S.E–N.W. post-glacial faults that has been observed is that on Rock street behind Fowler's Mill where a space of about one hundred and seventy feet of slate ledges has been laid bare. In this space sixty-one faults were observed which had been attended with displacement of the measures since their glaciation. In all of these faults, with one exception the *downthrow was on the north side,* and the hade of the faults was to the southwest. The sum of the displacement at these faults was five feet eight inches; the average throw for each fault being thus somewhat over one inch.

In one case only, a fault of half an inch had a downthrow on the *south side.* The diagonal faults which are not very conspicuous at this place, were not measured.

The heaviest throw seen at this place was five inches and very often an individual fault when traced along its course was found to vary in the amount of displacement. This was especially the case when the fault was complicated with a diagonal displacement, so that wedges of the slate would be raised above the general contour, or depressed below it; and occasionally a

rhombic block could be observed, lifted above the surrounding slate.

At almost every place in the city and east and west of it, where the glaciated ledges of the slates of the St. John Group could be observed, some displacement was seen, though often very slight. At the N.E. corner of the Church of England burying-ground, east of the city, there is a ledge which shows two slight faults ($\frac{1}{4}$ inch each) with a downthrow *on the south*, eastward of Courtney Bay, at its head, the slates at the shore and on the road, have about a dozen faults with throws varying from one half an inch to an inch; these in almost all cases have the downthrow *on the north side.*

A fuller account of these faults will be given in the next Bulletin of the Natural History Society of New Brunswick, with some conjectures as to the causes which have produced them.

St. John, N. B., Canada, November 1, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the new Iodine Bases.*—Several additional salts of the new iodonium bases, discovered by V. Meyer and Hartmann,* have been described by these chemists. The nitrate $(C_6H_5)_2I.NO_3$, obtained by neutralizing a concentrated solution of the free base with strong nitric acid, appears as a white crystalline precipitate, readily soluble in hot water, from which it separates on cooling in small plates or spear-like crystals. It fuses at 153°–154°, to a clear liquid which soon begins to decompose and evolve gas; exploding if the quantity is considerable. The acid sulphate is produced by adding sulphuric acid in slight excess to a strong solution of the free base, and evaporating. The crystalline mass is dissolved in alcohol and on adding ether, the salt separates in colorless crystals reacting acid to litmus. The acetate is obtained by agitating iodobenzene with caustic soda and adding acetic acid. On filtering the warm solution, it deposits on cooling crystals of the acetate, which melt at 120°. One of the most interesting salts is the periodide, obtained by mixing the iodide of the base with an alcoholic solution of iodine and triturating. Combination at once takes place producing a brownish red precipitate, which yields, on crystallization from alcohol, dark red lustrous crystals having the composition $(C_2H_5)_2I.I.I_2$ and fusing at 138.° The sulphides are remarkably similar in appearance to the sulphides of lead, thallium and antimony. On mixing a solu-

* This Journal, III, xlvii, 399, May, 1894.

tion of the free base with ammonium sulphide, a bright orange-red precipitate is thrown down, very similar to antimony sulphide, and stable at 0.° At the ordinary temperature, however, it soon begins to decompose, evolving white clouds of vapor and yielding a mobile oil. Analysis shows it to be the trisulphide $(C_6H_5)_2I.S.S.S.I(C_6H_5)_2$, its decomposition products being iodobenzene and phenyl-trisulphide. The normal sulphide $(C_6H_5)_2I.S.I(C_6H_5)_2$ is precipitated from solutions of the base by sodium sulphide, as a bright yellow precipitate, decomposing at ordinary temperatures into iodobenzene and phenyl-sulphide. Several double chlorides, formed with the chlorides of mercury, gold and platinum are also described. The free base is reduced by sodium amalgam, one molecule decomposing into benzene, water and hydrogen iodide, the latter substance precipitating a second molecule of the base as insoluble iodide. The solution of the free base precipitates solutions of the salts of the heavy metals exactly as ammonia and the fixed alkali hydroxides do. The physiological action of the chloride has been studied by Gottlieb. It is found to be very poisonous, its mode of action combining the characteristics both of the salts of lead and thallium with those of ammonia and the ammonium bases.—*Ber. Berl. Chem. Ges.*, xxvii, 1592, July, 1894. G. F. B.

2. *On an Anomaly in the Density of Nitrogen.*—In a paper to the Royal Society, Rayleigh has called attention to an anomaly which he has encountered in his attempts to determine the density of nitrogen prepared by different methods. He had already established the fact that this gas, prepared by Lupton's method, i. e., by passing air mixed with ammonia through a red-hot tube containing copper, is lighter by about one thousandth part than nitrogen prepared in the usual manner, by passing air alone over the red-hot copper. Moreover he observed that on substituting oxygen for air in the former process, in which case the whole of the nitrogen instead of only about one-seventh part, comes from the ammonia, the discrepancy was increased to about one half per cent. In explanation of this condition of things, it might be assumed (1) on the one hand, that the heavier nitrogen contained admixed oxygen, or (2) that on the other the lighter specimens contained some gas lighter than nitrogen. The former hypothesis would seem to be negatived by the large quantity of oxygen required for the purpose as well as by the precautions taken to get rid of all of the oxygen, using various methods. The latter seems no less improbable, since the only gases involved are water-vapor, ammonia and hydrogen; the two former being very readily removed, and the latter being certainly oxidized by the copper-oxide. Accordingly, further experiments were made, the nitrogen being prepared by the reduction of nitrogen monoxide or nitrogen dioxide, or by the ignition of ammonium nitrate, the gas obtained being in all cases passed over pure iron at a red heat, and carefully purified. In four experiments made on nitrogen prepared from NO by reduction with hot iron, the

mass of the gas contained in the globe used was 2·30143, 2·29890, 2·29816, 2·30182; the mean being 2·30008. Two experiments on nitrogen prepared by reducing N_2O by iron, gave 2·29869, 2·29940; the mean being 2·29904. Two experiments on nitrogen from ammonium nitrate, passed over hot iron, gave 2·29849, 2·29889; the mean being 2·29869. If now, we compare with these numbers, the values obtained from nitrogen prepared from the atmosphere, we find that in four experiments, the mass of the gas in the globe was 2·31017, 2·30986, 2·31003, 2·31007; the mean being 2·31003. Moreover, on removing the oxygen by placing air in a vessel containing a mixture of slaked lime and ferrous sulphate, the nitrogen gave the values 2·31024, 2·31010, 2·31028; mean 2·31020. Thus the result obtained from air in 1892 with hot copper 2·31026, that of 1893 by hot iron 2·31003, and that of 1894 by ferrous sulphate 2·31020 agree well together. It would, therefore, seem that the nitrogen prepared by the four chemical methods given is materially lighter than the nitrogen prepared from atmospheric air, the difference amounting to about 11 milligrams on the mass contained in the globe, or about one two-hundredth part of the whole. Moreover the lighter nitrogen did not become denser by standing for eight months. It was this anomaly in density that suggested to Rayleigh and Ramsay the possible presence in the air of some new constituent.*—*Proc. Roy. Soc.*, April, 1894; *Nature*, l, 157, June, 1894. G. F. B.

3. *On Carbon Boride.*—It has been shown by Moissan that when the electric arc is allowed to pass between two carbon electrodes agglomerated by means of a solution of boric acid and aluminum silicate, or when boron itself is placed in the electric arc, the carbon and boron unite to form carbon boride. It may be obtained in larger quantity by heating a mixture of 66 parts of amorphous boron and 12 parts of carbon made from sugar, in an electric furnace for six or seven minutes, by means of a current of 200–300 amperes and 70 volts. A black graphitoidal mass is obtained having a brilliant fracture. By treating this, first with fuming nitric acid and then with a mixture of nitric acid and potassium chlorate, the product is obtained in the form of a crystalline powder. Carbon boride may also be prepared by adding boron and carbon in excess to iron, and heating the whole in the electric furnace. Better results are obtained however by using copper or silver instead of iron; the crystals being better defined with the latter metal. Prepared in any of these ways carbon boride has the composition CB_6 and forms brilliant black crystals of sp. gr. 2·51. Chlorine attacks it below 1000°, but it is not affected by bromine, iodine or sulphur, at the softening point of glass, or by phosphorus or nitrogen at 1200°. Boiling acids do not act on it, nor do chromic acid, fuming nitric acid or concentrated iodic acid when heated with it in a sealed tube to 158°. At 500° no carbon dioxide is formed when the boride is heated in oxygen; but at 1000° it burns slowly and with more

* This Journal, III, xlviii, 345, October, 1894.

difficulty than the diamond. At a dull red heat potassium hydroxide attacks it, as also does a mixture of sodium and potassium carbonates. Though friable, carbon boride is hard and can be used to polish even the diamond, producing distinct facets.—*C. R.*, cxviii, 556, 1894. G. F. B.

4. *On the Carbides of Calcium, Barium and Strontium.*—By placing a mixture of 120 grams calcium oxide and 70 grams carbon in the crucible of the electric furnace and subjecting it to the action of a current of 350 amperes and 70 volts for 15 or 20 minutes, MOISSAN has obtained calcium carbide, the yield being from 120 to 150 grams. It has the composition CaC_2 and appears as a homogeneous black mass, distinctly crystalline and readily cleavable. The crystals are brilliant but opake and have a sp. gr. of 2·22. They are insoluble in all ordinary reagents, are not altered when heated in hydrogen or nitrogen at 1200°, or with silicon or boron at a bright red heat; neither sodium nor magnesium attacks it at the melting point of glass, nor does tin at a red heat or iron at a dull red; but at a higher temperature, an alloy of iron and calcium is formed which contains carbon. Dry chlorine does not attack it in the cold but at 245° it becomes incandescent and yields calcium and carbon chlorides. Bromine acts similarly at 350° and iodine at 305°. It burns in oxygen at a dull red heat, and in sulphur vapor at 500°. It rapidly decomposes water, developing heat and evolving almost pure acetylene. Fused chromic trioxide oxidizes calcium carbide, evolving carbon dioxide. Heated with absolute alcohol to 180° in sealed tubes it yields acetylene and calcium ethoxide.

Barium carbide is obtained by a similar reaction as a fused black brittle mass composed of large lamellar crystals, having a sp. gr. of 3·75 and a fusing point lower than the other carbides of this group. Strontium carbide has a lustrous crystalline fracture and a sp. gr. of 3·19. Both these carbides are decomposed by water, yielding the hydroxides and pure acetylene. Heated sufficiently in the gaseous hydracids, the carbide becomes incandescent. C_2Sr becomes incandescent in dry chlorine at 197 and C_2Ba at 140°—*C. R.*, cxviii, 501, 683, 1894. G. F. B.

5. *On the Size of the molecule of Mercurous chloride.*—The earlier determinations of vapor density in the case of mercurous chloride gave numbers agreeing with the formula HgCl. But since Odling showed that gold leaf immersed in the vapor became amalgamated, dissociation was inferred. V. MEYER and HARRIS now show that the gold leaf is instantly amalgamated in the vapor of mercurous chloride, but that it becomes pure gold again if allowed to remain in the vapor. Moreover by Meyer's method, the authors have determined the vapor density at the temperature of boiling sulphur (448°) and phosphorus pentasulphide (518°) and find their results to agree with the early ones in corresponding to the formula HgCl. A second series of experiments with a mixture of free mercury and mercuric chloride gave almost identical results. The bulb of the density apparatus was then made

of porous earthenware. A large amount of mercury vapor diffused through it when mercurous chloride was volatilized in it and was condensed on the surrounding glass vessel. Further when calomel is volatilized in a retort connected with a Sprengel pump, by which the pressure is reduced to about 30mm. the upper portion of the apparatus is covered with a layer of globules of mercury, a corresponding quantity of mercuric chloride being formed. Again pieces of caustic potash heated to the same temperature became covered with orange mercuric oxide when placed in the calomel vapor, and not black mercurous oxide. Hence the authors conclude that mercurous chloride is Hg_2Cl_2, the mercury in it not being univalent.—*Ber. Berl. Chem. Ges.*, xxvii, 1482, June, 1894. G. F. B.

6. *A Text-book of Inorganic Chemistry.* By G. S. Newth, F.I.C., F.C.S. 12mo, pp. xiv, 667. London and New York, 1894. (Longmans, Green & Co.)—The author has sought in this book to obviate many of the difficulties arising from the attempt to base a systematic course of elementary chemical instruction upon the periodic classification of the elements, by dividing it into three parts, the first of which is devoted to a brief sketch of the fundamental principles and theories of the science, the second to a study of the four typical elements hydrogen, oxygen, nitrogen and carbon, and the third to a systematic treatment of the elements according to the periodic law. The first part is especially worthy of notice since the more recent developments of the science in a physico-chemical direction are included in it, and are clearly though of course briefly, stated. Such subjects as the kinetic theory of gases, dissociation, electrolysis, critical temperature and pressure, osmotic pressure and thermo-chemistry, for example, are here included. The book is carefully written and appears fully up to date. The centigrade scale of temperatures is used exclusively and the metric system preferably; though we notice that the word "weight" for the most part is employed in the sense of "mass." G. F. B.

7. *An Elementary Chemistry.* By George Rantout White, A.M. 12mo, pp. xxx, 272. Boston, 1894 (Ginn & Company).—This book is a laboratory manual and is intended for beginners in chemistry. The first and second parts are devoted to experiments, the latter being the more advanced. The third part comprises the history and development of the laws and theories of chemistry. G. F. B.

8. *The mean density of the earth.*—Prof. Poynting's essay on the mean density of the earth has now been published. It contains a review of previous methods together with an account of the method of weighing by the ordinary balance which Prof. Poynting adopted. Newton in his Principia estimated that two spheres of the density of the earth, each a foot in diameter, would if separated by a quarter of an inch and left to their own attractions, take nearly a month to come into contact. Prof. Poynting points out that there is a mistake in the arithmetic, and that the

spheres would come into contact between five and six minutes. The mean density of the earth found by Professor Poynting is 5·49. Professor Boys result is 5·53.—*Nature*, Oct. 4, 1894, pp. 542–543. J. T.

9. *On the mean density of the earth.* (Communicated).—The last publication of the Philosophical Society of Washington, (Bulletin xii, 369–370 8 plates 7–10) gives a determination of the Mean Density of the Earth from two mountains in the Hawaiian Islands. Two distinct methods were used. In the case of Haleakala, astronomical latitudes were determined near the sea level on the north and south side of the mountain. These stations which were distant about 30 miles were connected by triangulation and by this means the deflection of the plumb line towards the mountain was ascertained. Contour lines for differences of elevation of 500 feet were established from the sea to the summit which is rather more than 10,000 feet high. Using these contours and a value of the mean density of the mountain derived both from determinations of the force of gravity and a study of the rock specimens, the attraction of the mountain was calculated. This compared with the total attraction of the earth gave an equation from which the earth's mean density was found.

In the case of Mauna Kea with an elevation of nearly 14,000 feet, contour lines could not be run, and the solution of the problem depends entirely on the determination of the differences of the force of gravity, combined with a value of the mountain density, from about 40 specimens of rock collected on both sides of the island between the lower and upper gravity stations.

Combining the results of both Mauna Kea and Haleakala a value of 5·35 was deduced for the mean density of the Earth.

At the end of the Bulletin is a table containing a list of all previous determinations which depend on pendulum or astronomical observations. The values given range from 4·67 to 6·77 and give a mean of 5·59.

The work in the Hawaiian Islands was done by Mr. E. D. Preston of the U. S. Coast and Geodetic Survey for the time being in the employ of the Hawaiian Government Survey.

10. *The source of friction electricity.*—C. Christiansen reviews the work of previous observers, and makes a number of experiments to ascertain the cause of frictional electricity. He arrives at the conclusion that it is to be sought in chemical separation or the relative turning of ions: and the action is analogous to that which takes place in electrolysis. Every atom has a charge which is positive or negative according as the atom acts as a *kation* or an *anion*. The author divides bodies into four classes. Class 1. Insulators or dielectrics. Bodies in which the ions are either fixed or can oscillate around their positions of equilibrium. Class 2. Metals in which the ions are either free or at least exchange their charges very easily. Class 3. Electrolytes in which the ions can move with more or less friction. Glass can be

included in this division. Class 4. Bodies analogous to water which include no ions or very few which permit movement. These can be called *hydrides.*—*Ann. der Physik und Chemie*, No. 11, 1894, pp. 401–431. J. T.

11. *Electrical conductivity of absolutely pure water.*—Kohlrausch and Heydeweiler describe the processes by which they prepared and tested samples of pure water. They endeavored to find the true conductivity of water by extrapolation from previous experiments. The value thus obtained for the conductivity of absolutely pure water at 18° C. is $0{\cdot}036 \times 10^{-10}$. The amount of residual impurity was estimated at a few thousandths of a milligram per liter, which is 10,000 times less than the amount of air normally absorbed from the atmosphere.—*Ann. der Physik und Chemie*, No. 10, 1894, pp. 209–235. J. T.

12. *Self induction and capacity of coils.*—C. Fromme from magnetic experiments shows that bifilar wound coils possess a small capacity, so long as their resistance does not exceed 1000 ohms. At 2000 ohms the capacity begins to reach an appreciable amount. Chaperon's coils, however, so far as they were tested up to 3000 ohms were found free from capacity and self induction. These coils are unifilar. The direction of the winding changes with each layer.—*Ann. der Physik und Chemie*, No. 10, 1894, pp. 236–266. J. T.

13. *Spirals with compensated self induction.*—The difference of potential between neighboring turns in an ordinary coil is in general small, so that the capacity is small and is only noticeable with currents of high frequency. In order to obviate this capacity, Tesla recommends winding a wire B parallel to the first wire A and connecting the end of A with the beginning of B.—*Lum. Electr.*, li, pp. 432–433, 1894. J. T.

II. Geology and Mineralogy.

1. *A pre-Olenellus fauna:* "On the Cambrian Formation of the Eastern Salt Range." By Dr. Fritz Noetling, F.G.S. *Records of the Geological Survey of India*, Vol. xxvii, part 3, pp. 71–86, August, 1894.—From researches made in the palæozoic rocks of the Salt Range of India by the Geological Survey of that country, Dr. R. D. Oldham points out* what are the accepted divisions of the Cambrian rocks of that region and gives numerous lists of the fossil remains recognised up to date. In these lists such genera as *Olenellus*, *Hyolithes*, *Conocephalites and Neobolus* are recorded. There was however considerable confusion and mixture of horizons in the succession as known. Dr. Noetling has gone carefully into the natural succession of the Cambrian and newer palæozoic strata of the Eastern Salt Range. He separates the upper and middle portion of the Palæozoic from the lower and Cambrian portion.

* Manual of the Geology of India, Chapter V, p. 113 *et seq.*, Calcutta, 1893.

An historical sketch of the work done by Mr. Wynne, by the late Dr. Stoliczka, by Dr. Waagen of Vienna, by Dr. Warth, Mr. Middlemiss and Mr. Datta is then given. Dr. Noetling divides the Cambrian of the Eastern Salt Range of India into *four* groups which are in turn divisible into a number of zones or horizons. These four divisons of the Cambrian are as follows:

In descending order:

4. Bhaganwalla group, or Salt Range pseudomorph zone.
3. Jutana group, or Magnesian sandstone.
2. Khussak group, or Neobolus beds.
1. Khewra group, or Purple sandstone.

No fossil remains have yet been found in the Khewra group—but the Khussak group has yielded an interesting fauna divisible into *five* distinct zones at the top of which is the "*Olenellus zone*," so that there are four zones of fossiliferous strata below this Olenellus zone which may be termed pre-Olenellus zones.—These are the five zones of the Khussak group, in descending order:—

V. Olenellus zone.
IV. Neobolus zone.
III. Upper Annelid sandstone.
II. Zone of *Hyolithes Wynnei.*
I. Lower Annelid zone.

In the "Jutana Group"—above the Khussak group Dr. Noetling ascertained the following succession of strata in descending order:—

X. Upper Magnesian sandstone.
IX. " passage beds.
VIII. Middle Magnesian sandstone.
VII. Lower passage beds.
VI. " Magnesian sandstone.

In the Lower Magnesian sandstone, Dr. Noetling obtained a species of *Stenotheca* which he correlates with Billing's species: *Stenotheca rugosa, var. aspera* and an obscure *Lingulella.* That author has not attempted to make a critical examination of the fossil remains collected during the exploration but with the sanction of the Director of the Geol. Surv. of India these were sent to Dr. Waagen for determination. We are all anxious to hear the results of Dr. Waagen's observations inasmuch as a considerable proportion of the fauna is a pre-Olenellus fauna. Dr. Noetling is apparently satisfied to class all these sedimentary deposits under the term Cambrian without adopting any new term to include the pre-Olenellus fossils. H. M. A.

2. *The Mineral Industry, its Statistics, Technology and Trade for 1893;* Annual, Vol. II. Edited by R. P. Rothwell, 8°, xlii+894 pp. Scientific Publishing Co., New York.—The compilation of this voluminous year-book is the result of the development of the annual statistical numbers of the *Engineering and Mining Journal.*

The volume under consideration contains a vast amount of statistics concerning the production and value of the mineral

products of the world, as well as their movement in trade. It also embodies many special articles on the history and advancement of mineral industries, on the uses and occurrences of various products, on methods of mining and smelting, and so on, many of which are by specialists of the highest eminence in their several branches.

The book is of interest, not only to statisticians and those engaged in mining and the related industries, but also to those who desire to keep themselves informed on mining and metallurgical topics from a scientific point of view. H. L. W.

3. *Catalogue of Minerals.* GEORGE L. ENGLISH. 16th edition, 1894, pp. 124.—This catalogue is more than an illustrated price list of minerals. The classified list, with its alphabetical index, constituting 78 pages, presents in classified order the names of all the minerals and their varieties described in Dana's new "System of Mineralogy," 1892 edition, with the chemical formula, hardness and specific gravity of each. The catalogue will be useful to all mineral collectors who wish to keep up with the progress to the science.

III. BOTANY.

1. *Vegetable Resources of India.*—In the Kew Bulletin of Miscellaneous Information for September, 1894, is an abstract of Dr. GEORGE WATTS' recent memorandum on the resources of British India. The following notes are of general interest:

That part of British India treated of by Dr. Watt, comprises about 700,000,000 acres, on which lives a population of more than 220,000,000. The total acreage under *wheat* is over 20,000,000 acres. "In 1891–92, under exceptional circumstances of demand n Europe, Indian wheat was exported to the value of nearly 144 millions of rupees."

Tea.—It is well known that the indigenous tea plant has proved in India better than the acclimatized. The total acreage under tea is 334,845 acres.

The first commercial sale of Indian tea was in Calcutta more than fifty years ago. The exports in 1891–92 were 120,000,000 lbs. In the same year Ceylon exported about 70,000,000 lbs., and thus proves a formidable competitor.

Coffee.—It is believed that coffee has been cultivated in India for more than two centuries. The acreage is 125,000 acres:

Sugar.—Dr. Watts gives an interesting account of the fluctuations in the India sugar trade. There has been a steady decline of the export trade in refined sugar since 1845. The production of beet sugar in Europe has been: to close the markets which formerly received the refined sugar of India, and in the second place to "throw on the world large quantities as abnormally cheap cane sugar, which sought an outlet in India." The raw sugar in India, after making a correction for the foreign traffic, comes to 2,600,000 tons, or, say, 28 lbs. per head of the population.

Cinchona.—On the 31st of March, 1893, it was estimated that the matured plants on all of the plantations might be estimated at ten millions.

Indigo.—There are in India 2,762 factories and 6,032 vats, and these give employment to 356,675 persons during the working season irrespective of the agricultural labor to produce the plants. Last years' export of Indigo was 126,706 cwt.

Cotton.—It appears that the cultivation of cotton has not been developed on strictly scientific principles. It seems to Dr. Watts that selection of seed and the cultivation of specially selected plants might easily improve the Indian crop of any district by 50 per cent. The total area under cultivation is 9,000,000 acres.

Other Fibres.—Very little has been done in utilizing the remarkable fiber plants of native origin. The most promising possibilities appear in every direction. It is said that the fiber of Marsdenia tenacissima is far superior to Rhea. Its tensile strength is much greater than that of the finest hemp.

Cutch.—The process of boiling down the heart wood of Acacia catechu into a tanning extract, dates from remote antiquity. The modern methods of manufacture, though improved in many particulars are still far from economical. The export averages something over 2,200,000 cwt. annually.

Dr. Watts presents a most interesting account of the relations of Indian agriculture to the plants of other countries, pointing out that not far from 50 per cent of the prevalent cultivated and wild vegetation has been imported by India within historic times.

It is encouraging to note that various societies are coöperating with governmental departments in developing possibilities.

The August Bulletin of Miscellaneous Information from the Royal Gardens in Kew, contains a most interesting summary relating to *bananas* and *plantains*. The subject is dealt with very fully, especially with regard to the economic uses. A few of the statistics are here given :

During the year 1892, 13,000,000 of bunches of ripe bananas were imported into the United States. Each bunch usually consists of 80 to 200 bananas and weighs from 30 to 90 lbs.

Plantain meal, a food of great antiquity, has lately attracted considerable attention. It appears that some of the product has been made from unripe bananas. In all the samples, starch is more abundant than sugar. G. L. G.

2. *Grafting.*—M. Lucien Daniel (Revue générale de Botanique, 15 Sept. 1894) has published the results of interesting experiments in grafting herbaceous plants, especially different vegetables. His conclusions are as follows:

First, the flavor of vegetables can be made to vary by grafting them on vegetables of a different flavor.

Second, grafting flower pits at a suitable period retards the flowering of Cruciferæ. This delay enables us to suppress cross-breeding and consequently permits us to preserve varieties pure.

Third, seeds from a graft are better than those from the same plant ungrafted. Besides the immediate advantage which results from this, it may be possible for us in this way to regenerate and preserve varieties.

Fourth, herbaceous plants which are blanched cannot be grafted.

Fifth, from seeds produced from grafts new varieties can be created. G. L. G.

3. *Inflorescence in Descriptive Botany.* By M. F. Hy. (Revue gén. de Botanique, 15 Oct. 1894).—The author has introduced new terms descriptive of the multifarious forms of compound flower clusters. The terminology itself does not appear to possess any marked advantage over that which has been employed in more recent German treatises, but in the projections in a diagramatic form some curious relations are brought out which render the communication of considerable value.

The relations of inflorescence to the environment and to systematic affinities are not sufficiently dealt with. G. L. G.

4. *Researches on the Structure and affinities of Terebinthaceae.* By M. Jadin. (Annales des sciences naturelles, xix, I, 1894).—The following conclusions are reached: The stem in this Order is always characterized by canals of secretion developed in the liber. These canals are protected by enveloping fibers. This character is so marked that it should be taken as the most important character of the family. Second, there are no characters drawn from the anatomy of the stem by which the genera can be identified. Nevertheless in certain cases, such characters really aid when they are added to those of gross anatomy.

Third, the character drawn from the presence or absence of canals in the pith cannot always be taken as an important character. It however serves for certain cases.

Fourth, It does not appear that climate has any important influence on the development of the secreting canals in the pith. The following genera are excluded: *Ganophyllum*, Bl. *Filicium*, Thw. *Corynocarpus*, F. *Paiveusea* Welw. *Juliania*, Schlecht. All of these are excluded on account of anatomical peculiarities. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The following is a list of the papers presented at the meeting of the National Academy held in New Haven, Oct. 30–Nov. 1:

William A. Rogers: An indirect experimental determination of the energy of obscure heat; Determination of the errors of the circles of an electrotype copy of Tycho Brahe's altitude azimuth instrument now in possession of the Smithsonian Institution.

Hubert A. Newton: The Winnebago County, Iowa, meteorites, and the meteor.

George W. Hill: Literal expression for the motion of the moon's perigee.

WILLIAM H. BREWER: Atmospheric dust and aqueous precipitation in Arctic regions.

SETH C. CHANDLER: Further researches on the polar motion.

THOMAS C. MENDENHALL: The relation of gravity to continental elevation; The legal units of electrical measure.

CHARLES S. HASTINGS: On derived equations in optics; On a method of eliminating secondary dispersion, using ordinary silicate glasses only.

THOMAS B. OSBORNE: The chemical nature of diastase.

CHARLES E. BEECHER: Some features in the development of brachiopods.

HENRY S. WILLIAMS: On the presence of Devonian fossils in strata of Carboniferous age.

JOHN S. BILLINGS: On the influence of insolation upon Culture Media, and of desiccation upon the vitality of the bacillus of typhoid, of the Colon bacillus, and of the Staphylococcus aureus.

WILLIAM L. ELKIN: Report on photographing meteors.

CHARLES A. WHITE: Biographical memoir of F. V. Hayden.

A. E. VERRILL: Geographical and bathymetrical distribution of the deep sea echinoderms, discovered off the American coast, north of Cape Hatteras.

A. A. MICHELSON: On the effect of pressure in broadening spectral lines.

JAMES HALL: Remarks upon the progress of work upon a handbook of the brachiopoda; Note upon the occurrence and distribution of the dictyospongidæ in the Devonian and Carboniferous formations.

S. P. LANGLEY: Infra red spectrum.

J. W. GIBBS: On a certain theorem in theoretical dynamics.

Boston Society of Natural History, Proceedings, vol. xxvi, Boston, 1894,—several interesting geological papers have appeared in the recently issued parts of this volume.

Parts II–III contain:

Facetted pebbles on Cape Cod, Mass, by W. M. Davis, pp. 166–175, with plates I–II.

Some typical Eskers of Southern New England, by J. B. Woodworth, pp. 197–220.

On the distribution of Earthquakes in the United States since the close of the Glacial Period, by N. S. Shaler. pp. 246–256.

The geographical development of alluvial river terraces, by R. E. Dodge, pp. 257–273.

The preglacial channel of the Genessee River, by A. W. Graham, pp. 359–369.

Occasional papers, IV.

Geology of the Boston Basin, by Wm. O. Crosby, vol. 1, Part II, Hingham, pp. 179–288, with plates 6, 7 and 8. 1894.

Geotektonische Probleme; von A. Rothpletz, p. 175, fig. 107, plates 10 (E. Koch), Stuttgart, 1894.

Die Maschinellen Hilfsmittel du Chemischen Technik; von A. Parnicke, p. 320, fig. 327 (H. Bechhold). Frankfurt, 1894.

University of California, Bulletin of Dept. of Geology. Vol. I. Berkeley, 1894.

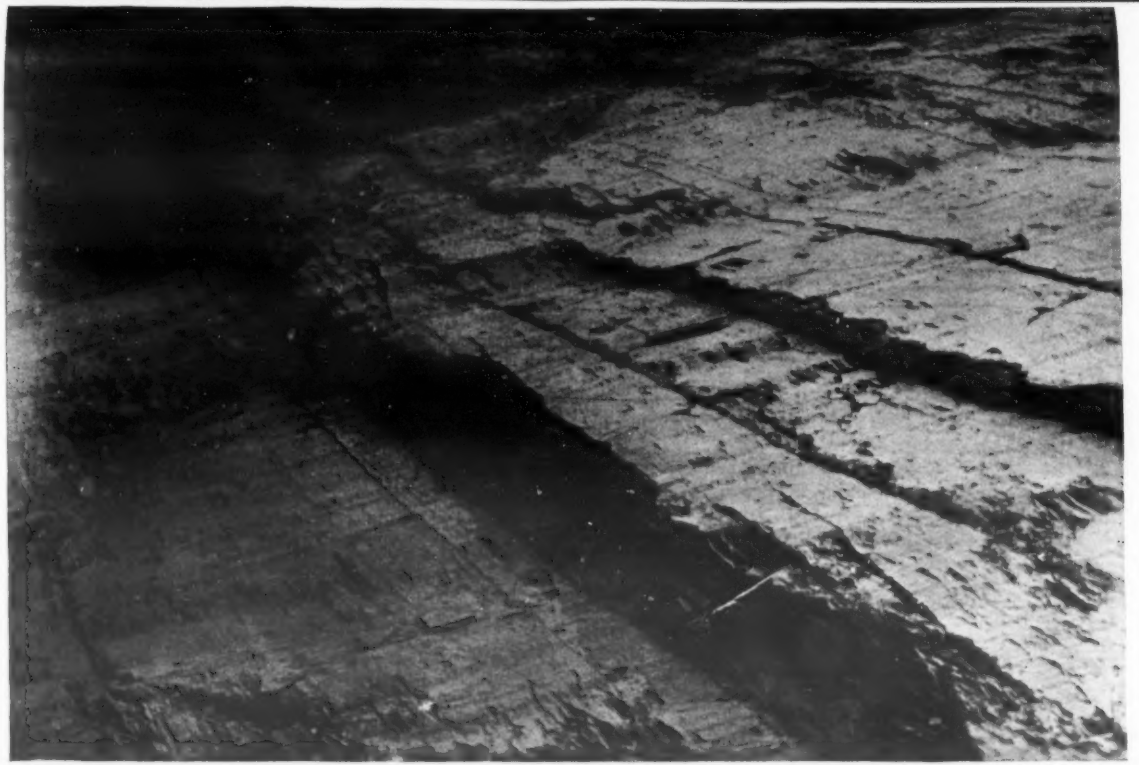
No. 5. The Lherzolite-Serpentine and Associated Rocks of the Potrero, San Francisco; by Charles Palache, pp. 161–179.

No. 6. On a rock from the vicinity of Berkeley, containing a new soda Amphibole; by Charles Palache. pp. 181–191, and two plates.

No. 7. The Geology of Angel Island; by F. Leslie Ransome (with a note on the Radiolarian chert from Angel Island, etc., by G. J. Hinde), pp. 193–240, plates 12–14.

OBITUARY.

WILLIAM TOPLEY, an active promoter of geology in Great Britain and for several years in charge of the Jermyn street office of the Geological Survey in London, died at the age of 53, on the 30th day of September.



EXPLANATION OF THE PLATE.

A ledge of clay-slate on City Road, St. John, N. B., Canada, showing a series of post-glacial faults. The view is taken looking southward up the hillside.

When exposed to the weather the sharp edge of the slate along the fault crumbles away from the effect of frost, and in the larger faults is only found perfect when the fault has been freshly exposed. In most of the faults here figured the projecting edge has thus suffered from exposure, except where they approach the covering of soil. The course of the glacial striæ is S. 15 E.

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